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Vol. VII — JUNE, 1959 — No. 2

THE LABORATORY EQUIPMENT OF THE EARLY MEDIÆVAL CHINESE ALCHEMISTS

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I. Introduction

The art of alchemy was practised in China mainly by the Taoists, who held the belief that it was feasible to prolong human life indefinitely. There were several ways and means of doing this, one of which involved the preparation of an elixir. To understand their alchemical processes it is necessary to make a study of their laboratory apparatus and equipment. For this purpose the richest source available to us is the *Tao Tsang*[1] (Taoist Patrology), a collection consisting of 1,464 Taoist texts.

It may be worth while to give a short description of the origin of the Taoist Patrology. We shall follow the study of Chhen Kuo-Fu[2] (8). During the Khai-Yuan[3] reign-period (+713 to +741) the Emperor Hsüan-Tsung[4] collected some three thousand Taoist works, and in the year +748 duplicate copies of these texts were made. A few years later most of these books were destroyed during the two uprisings staged by An Lu-Shan[5] and Shih Ssu-Ming[6]. A second collection during the Hsien-Thung[7] reign-period (+860 to +873) consisting of some five thousand books also suffered the same fate when Huang Chhao[8] tried to overthrow the government. Another collection was made during the Sung Dynasty, and the Emperor Chen-Tsung[9] ordered first Wang Chhin-Jo[10] and then Chang Chün-Fang[11] to catalogue it. This work was completed by +1019 and was named the *Ta Sung Thien Kung Pao Tsang*[12] (The Precious Patrology of the Celestial Palace collected in Great Sung). Further texts found during the reign of Hui-Tsung[13] (+1101 to +1125) increased the collection from 4,565 to 5,387. During the Chêng-Ho[14] reign-period (+1111

to +1117) blocks were made for the first time to get the whole collection printed. This was the *Wan Shou Tao Tsang*[15] (The Immortal Taoist Patrology). We may note here that of the writings of the Greek alchemists no manuscript survives that is older than about +1000. The Chinese tradition, however, gives us texts which were already stabilised in printed form by about +1115.

The *Wan Shou Tao Tsang*[15] unfortunately was not as immortal as suggested by its name, for before long it became a victim of war and fire. Some of the blocks fell into the hands of the Jurchen Tartars. In +1164 the Emperor Shih-Tsung[16] of their Chin Dynasty compiled the *Ta Chin Hsüan Tu Pao Tsang*[17] (The Precious Patrology of the Mysterious Capital [i.e. the Taoist Church] collected in the Great Chin Dynasty) from these blocks and from those made for the additional Taoist texts he managed to find. Completed within two years this new Taoist Patrology consisted of 6,455 books. However, in +1202 the Thien Chhang Kuan[18] Monastery where the blocks were preserved was burnt to the ground by fire. In +1244 Sung Tê-Fang[19] printed the *Hsüan Tu Pao Tsang*[20] (The Precious Patrology of the Mysterious Capital [i.e. the Taoist Church]) consisting of 7,800 books—within a decade some of the blocks were burnt by the Yuan emperor Hsien-Tsung[21]. Further destruction of the remaining blocks and texts was carried out by Shih-Tsu[22] when the doctrines of Taoism and Buddhism came into open conflict at his court. This inflicted the greatest blow of all on Taoist literature, much of which was lost for ever.

Efforts were made during the Ming Dynasty (+1368 to +1661) to restore the Taoist Patrology. In +1444 the *Chêng-Thung Tao Tsang*[23] (The Taoist Patrology of the Chêng-Thung reign-period) was printed, and in +1607 a supplement called the *Wan-Li Hsü Tao Tsang*[24] (Supplementary Taoist Patrology of the Wan-Li reign-period) was compiled. The blocks were safely preserved until the end of the last century when they were completely burnt during the Boxer Rebellion. Between 1923 and 1926 the Commercial Press in Shanghai reprinted the collection of the *Chêng-Thung Tao Tsang*[23] and the *Wan-Li Hsü Tao Tsang*[24] preserved in the Pai Yün Kuan[25] Monastery at Peking. The texts available to us nowadays generally come from this last edition.

In 1933 Tshao Yuan-Yü[26] first made a study (34) of Chinese alchemical apparatus. He published an article in Chinese entitled "The Apparatus, Preparations and Methods of the Ancient Chinese Alchemists" and two abstracts in English were written by Barnes (1) and Wilson (40) in the following years. Li Chhiao-Phing[27] (19) has also devoted a few pages to alchemical apparatus in his book. Further short descriptions in German and in Chinese have recently been given by Huang Tzu-Chhing[28] (17) and Yuan Han-Chhing[29] (42) respectively. In the present article we have drawn materials more exhaustively from the Taoist patrology designing to treat the subject more thoroughly than either Tshao, Li, Huang or Yuan. Some of our interpreta-

tions, such as that of the East Asian types of still, are essentially different from previous suggestions, and others, like the method of distillation *per descensum* using a bamboo tube, have not before been mentioned.

II. The Sources

Our sources include more than twenty different alchemical texts, all from the *Tao Tsang*. Since they will be referred to very often it will be convenient to make a list of them giving where possible the names of their authors, the dates when they were written and also their numbers in the standard catalogues.

Text	*Author*	*Date*	*Wieger catalogue number*	*Wêng Tu-Chien*[34] *catalogue number*
Huan Tan Pi Chüeh Yang Chhih Tzu Shen Fang[30]. (Secret Formulae of the Cyclically Transformed Elixir and Thaumaturgic Methods of Nourishing the [Divine] Embryo.)	Hsü Ming-Tao[31]	late +12th cent.	W/229	E/232
Thai Chhing Shih Pi Chi[32]. (The Records in the Rock Chamber; a Thai-Chhing Scripture.)	compiled by Chhu Tsê[33]	early +6th cent., but with materials of +3rd cent.	W/874	E/880
Huang-Ti Chiu Ting Shen Tan Ching Chüeh[35]. (Explanation of the Yellow Emperor's Manual of the Nine-Vessel Magical Elixir.)	unknown	Thang or Sung, but incorporating some materials as old as the +2nd cent.	W/878	E/884
Ta Tung Lien Chen Pao Ching Chiu Huan Chin Tan Miao Chüeh[36]. (Mysterious Teachings on the Nine-fold Cyclically Transformed Gold Elixir according to the True and Precious Manual of Transmutations of the Grand Void.)	Chhen Shao-Wei[37]	Thang; not later than +9th cent.	W/884	E/890
Thai Shang Wei Ling Shen Hua Chiu Chuan Tan Sha Fa[38]. (Methods of the Exalted Guardian for the Marvellous Thaumaturgical Transmutation of Ninefold Cyclically Transformed Cinnabar.)	unknown	unknown	W/885	E/891
Chiu Chuan Ling Sha Ta Tan[39]. (The Great Ninefold Cyclically Transformed Cinnabar Elixir.)	unknown	unknown	W/886	E/892
Yü Tung Ta Shen Tan Sha Chen Yao Chüeh[40]. (True and Essential Teachings about the Great Magical Cinnabar of the Jade Chamber.)	unknown	unknown	W/889	E/895
Tan Fang Hsü Chih[41]. (Chymical Elaboratory Practice.)	Wu Wu[42]	+1163	W/893	E/899
Shih Yao Erh Ya[43] (Synonymic Dictionary of Minerals and Drugs.)	Mei Piao[44]	+806	W/894	E/900

Text	*Author*	*Date*	*Wieger catalogue number*	*Wêng Tu-Chien*[34] *catalogue number*
Chih-Chhuan Chen-Jen Chiao Chêng Shu[45]. (Revised Technical Methods of the Adept Ko Hung.)	attrib. Ko Hung[46]	ascr. +4th cent. but probably later	W/895	E/901
Kan Chhi Shih-Liu Chuan Chin Tan[47]. (The Sixteenfold Cyclically Transformed Gold Elixir, prepared by the "Responding to the Pneuma" Method.)	unknown	Sung (before +14th cent.)	W/904	E/910
Hsiu Lien Ta Tan Yao Chih[48]. (Essential Hints on the Preparation of Powerful Elixirs.)	unknown	Sung (before +14th cent.)	W/905	E/911
Chin Hua Chhung Pi Tan Ching Pi Chih[49]. (Confidential Hints on the Manual of the Heaven-Piercing Golden Flower Elixir.)	Phêng Ssu[50]	+1225	W/907	E/913
Huan Tan Chou Hou Chüeh[51]. (Handy Formulae for Cyclically Transformed Elixirs.)	attrib. Ko Hung[46]	ascr. +4th cent.	W/908	E/914
Chu Chia Shen Phin Tan Fa[52]. (Methods of the Various Schools for Magical Elixir Preparations.)	Mêng Yao-Fu[53], also called Hsüan-Chen-Tzu[54]	Sung (before +14th cent.)	W/911	E/917
Chhien Hung Chia Kêng Chih Pao Chi Chhêng[55]. (Perfected Precious Compendium of Lead, Mercury and Gold [Elixirs].)	Chao Nai-An[56]	+808	W/912	E/918
Thung Hsüan Pi Shu[57]. (The Secret Art of Penetrating the Mystery.)	Shen Chih-Yen[58]	+864	W/935	E/941
Thai-Chi Chen-Jen Tsa Tan Yao Fang[59]. (Tractate of the Supreme-Pole Adept on Miscellaneous Elixir Recipes.)	unknown	unknown, but perhaps Sung on account of the philosophical significance of the pseudonym	W/939	E/945
Kêng Tao Chi[60]. (Collection of Procedures of the Golden Art [Alchemy].)	unknown	unknown, but after +1144	W/946	E/952
Chou I Tshan Thung Chhi[61]. (The Kinship of the Three; or, the Accordance of the Book of Changes with the Phenomena of Composite Things.)	Wei Po-Yang[62]	mid +2nd century; traditional date +142	W/990	E/996
Yün Chi Chhi Chhien[63]. (The Seven Tablets of the Cloudy Satchel.)	Chang Chün-Fang[64]	between +998 and +1022	W/1020	E/1026
Shang-Yang-Tzu Chin Tan Ta Yao Thu[65]. (Shang-Yang-Tzu's Illustrations for the Treatise on the Main Essentials of Gold Elixirs.)	Chhen Chih-Hsü[66]	+1331	W/1054	E/1060

For the sake of simplicity only Wieger's numbers will be quoted for the above texts in what follows.

III. The Equipment

(1) *The Laboratory Bench*

The Chinese alchemist's version of the modern laboratory bench was the *than*[67] (lit. platform or altar). No specific rules were laid down with regard to its dimensions and constructions. W/904 (p. 8*a*), a Sung book, gives an illustration of it (Fig. 1) together with the following explanatory notes:

> "The *tsao*[68] (furnace) is the *yao-lu*[69] (chemical stove). The *ting*[70] (vessel) is called the *sha-ho*[71] (cinnabar enclosure). The *shen-shih*[72] (magical reaction-chamber) is the *hun-tun*[73] (world of chaos)".

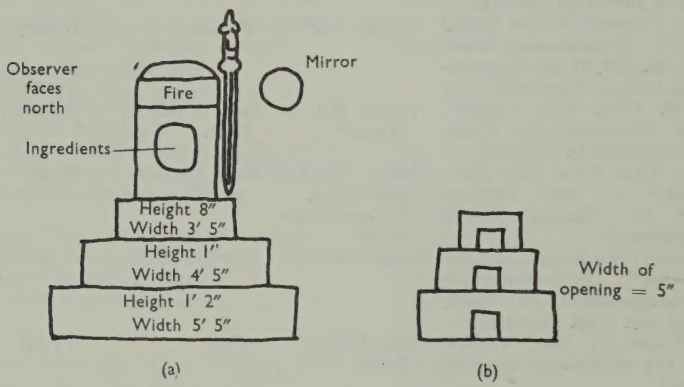


Fig. 1. Stove platform from W/904 (Sung).

The same text (p. 7*b*) describes the diagram saying,

> "Build a *than*[67] (platform) of three stages, with a (total) height of 3 ft. 6 in. The platform is square with a perimeter of 10 ft."

Note that this description does not coincide with the dimensions given in the diagram itself.

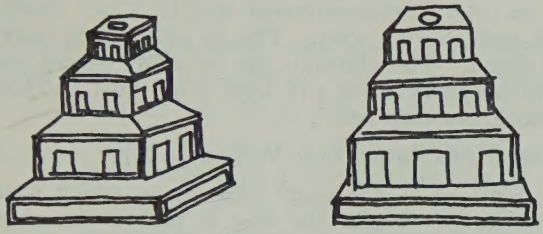
In W/893 (p. 5*b*), also a Sung book, we find two illustrations of the *lung hu tan thai*[74] (the Dragon-and-Tiger platform) (Fig. 2) and also the following description:

> "The *Tshan Thung Lu*[75] (Records of the Kinship of the Three) states, 'below the *lu*[76] (stove) is the *than*[67] (platform), which consists of three stages put one over the other. Each stage faces the eight directions and has eight openings'."

The construction of the *than*[67] was by no means standardized in the Sung as can be seen from another example in Fig. 3 taken from W/1020 (ch. 72, p. 11*b*). The text says, "The *than* can be so constructed as to suit one's convenience". This implies that there were no fixed rules in the construction of the *than*[67],

but that it could be made to suit the circumstances, such as the size of the stove and the size of the laboratory.

It is curious to see a stepped stove platform looking very like these in the Syriac alchemical texts of the +10th or +11th century (though the MSS. were not written till the +16th) as studied by Berthelot & Duval (4), p. 113.



(a) (b)

Fig. 2. Stove platforms from W/893 (Sung).

(2) *The Stoves* lu[76] *and* tsao[68]

Although the word *tsao*[68] generally refers to the kitchen stove, the two words *lu*[76] and *tsao*[68] both mean the heating apparatus of the alchemists which took many different forms. As the texts do not employ consistent terminology, in certain cases the heating apparatus may be taken to mean a stove or furnace, while in other cases it must mean an oven or combustion-chamber.

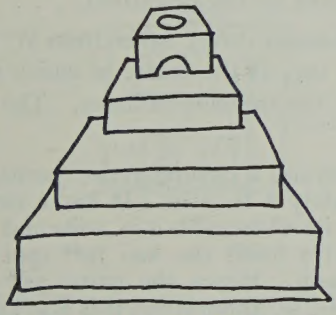


Fig. 3. Stove platform from W/1020 (Sung).

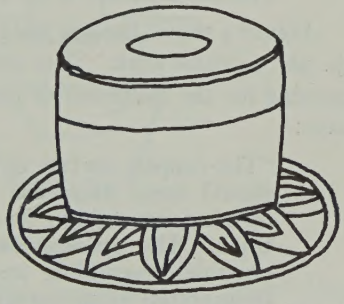


Fig. 4. Stove from W/1054 (Yuan).

W/1020 (ch. 72, p. 11*a*), a Sung text, describes one form of stove saying,

> "The *lu* (stove) forms the walls of defence for the *ting*[70] (reaction-vessel). Without the walls there would be evil influences (coming from outside). From top to bottom it resembles the *phêng hu*[77] pot and from side to side it symbolizes the Five Sacred Mountains (*wu yo*[78]). The platform consists of three stages, while the combustion-chamber has eight openings.

> The twelve cyclical signs and the months follow the (Pei-)Tou[79] (the Great Bear). . . . The *hua chhih lu*[80] (stove for evaporating vinegar) is 4 ft. high, 6 in. thick and has an internal circumference of 3 ft. 5 in. The openings measure 2 in. and they are eight in number".

The same text (p. 11*b*) also tells us about the *thai i lu*[81] stove. It says,

> "The *thai i lu* is placed over the platform. It is 2 ft. high, 6 in. thick and has an internal circumference of 3 ft. 5 in. Each opening is 2 in. high and half an inch wide. The 12 projections (*chih*[82]) are one inch wide all round. The platform can be made to suit one's convenience. Again the *hua chhih lu*[80] is 4 ft. high, 6 in. thick and has eight openings. It also has a two-inch rim. . . ."

Below is another description from W/904 (p. 7*b*):

> "On the platform is the *tsao*[68] (stove), on which is placed the *ting*[70] (reaction-vessel). Within the *ting* is placed the *shen-shih*[72] (magical reaction-chamber)".

A text of the Liang period, W/874 (p. 14*a*) gives an account of the construction of the *tan lu*[83] (elixir stove) saying,

> "Iron rods are fixed at the bottom of the stove. There should be, say, twelve or thirteen of them, each being 1 ft. in length and with a cross-section of 0·4 in. square. They are put in position (so as to form a grate) over the hollow space (*chhien*[84]) at a distance of 0·2 in. from one another. There is an empty space beneath the rods, which are placed two inches above ground (or rather above the base of the stove). The *tan lu* has an opening four and a half inches wide at the centre. The openings in front of and behind (the stove) enable air to pass in and out. The fire is lit above the rods and is fanned by the air current. . . ."

Figure 4 shows the *yen yüeh lu*[85] (inverted-moon stove), taken from W/1054 (p. 9*b*), a Yuan work. The stove has a flat top, at the centre of which is an opening for the container or crucible and for the emission of flame. The text says:

> "The (upper) surface of the *lu*[76] (stove) has a circumference (perhaps it should mean diameter) of approximately 1 ft. 2 in. It has a central opening measuring 1 ft. across. The rim all round is 2 in. wide and 2 in. thick. The opening faces upwards (to hold) the *huo fu*[86] (pot and crucible) resembling an upturned moon. Hence the name *yen yüeh lu* (inverted-moon stove). In Chang Sui's[87] annotations it is also known by the name *wei kuang ting*[88] (reaction-vessel of intense brightness)".

It seems likely that the *yen yüeh lu*[85] was the stove referred to by Wei Po-Yang[62] in the mid +2nd century in W/990 (ch. 1, p. 32*b*).

W/878 explains how the crucible was placed over a tripod inside the *tsao* (combustion-chamber; oven). It says (ch. 7, p. 4*a*):

> ". . . Within the *tsao* (combustion-chamber) is placed an iron tripod, which is best made of cast-iron (*sêng thieh*[89]). The *yao fu*[90] (closed

vessel) is placed over the tripod and adjusted until it is in the centre of the chamber. Care should be taken so that it does not incline to one side. The four sides should be about three and a half inches away from the wall of the chamber. The chamber should be two inches higher than the vessel. Rice-husk (fuel) should be regularly placed around the four sides of the crucible and more must be added as heating progresses. This is necessary for fear of uneven heating due to the varying intensity of the fire".

For ordinary heating the containing vessel was simply placed over the stove and fire was applied below. This is shown in Fig. 5 taken from the Sung text W/1020 (ch. 72, p. 20*b*). Another example is given in W/939 (p. 5*a*). It shows *yang lu*[91] stoves (Fig. 6), which employed a strong fire (*wu huo*[92]).

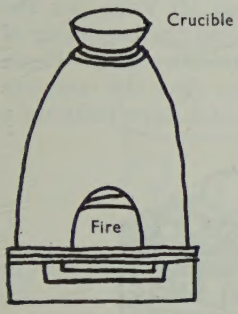


Fig. 5. Stove from W/1020 (Sung).

Curious stoves which may well have had alchemical use are to be seen in Chinese museums. For example the Archaeological Institute of Academia Sinica in Peking has a flat conical pottery object shaped rather like a mountain having holes for escape of fumes from burning charcoal or other fuel, and four cupped holders to take oval lidded pots, surrounding a chimney at the top of the stove. This apparatus, which was excavated at Yü-hsien[93] in Central Honan, could have served very well for continuous slow heating.[a]

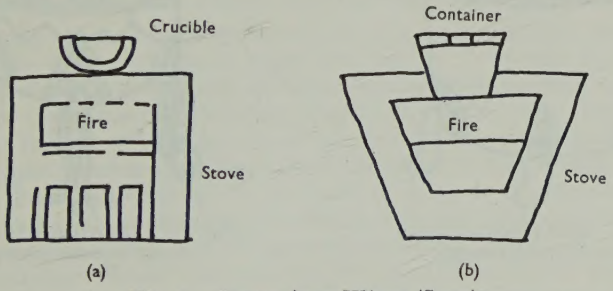


Fig. 6. Stoves from W/939 (Sung).

(3) *The Reaction-Vessels* ting[70] (*tripod, container, cauldron*) *and* kuei[94] (*box, casing, container, aludel*)

The word *ting* normally refers to the tripod cauldron, such as the bronzes so well known in Chinese archaeology, but the alchemists' apparatus known by this name referred not only to vessels of this kind but also to various other forms of reaction-vessels to which fire was applied externally. Perhaps the best distinction between the *lu*[76] (stove; combustion-chamber) and the *ting* is that

[a] It has been figured in *Khao Ku Thung Hsün*[95], 1955.

the former had fire within it whereas the latter was surrounded by fire. The *ting* itself might contain an inner reaction-chamber in which the ingredients were placed.

The earliest account of the reaction-vessel is found in the +2nd century *Tshan Thung Chhi* of Wei Po-Yang[62] (W/990, ch. 3, p. 11*b* ff.). It says[b]:

> "The Song of the *ting* (reaction-vessel): Its circumference is three-five (i.e. 1 ft. 5 in.) (and its thickness is) one inch and a tenth (i.e. 1·1 in.). The circumference of the mouth is four and eight (i.e. 12 in.). Its lips are 2 in. thick. The total body height is 12 in. (i.e. 1 ft. 2 in.; 10 Chinese in. = 1 Chinese ft.), with an even thickness throughout. With its belly set erect it is to be warmed up gently (over the stove). (The *chhi* of) Yin (i.e. the reaction-vessel) stays above, while (that of) Yang (i.e. the fire) runs below. Use a strong fire during the end and the beginning of each (lunar) month, but a gentle fire during the middle of it. Begin heating for 70 days, and after the end of another 30 days the contents are to be properly mixed and heated for a further 260 days (making a total of 360 days, i.e. twelve lunar months) . . .".

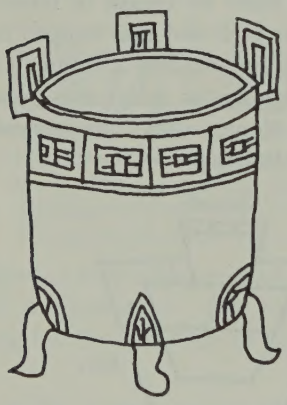


Fig. 7. Gold reaction-vessel from W/1020 (Sung).

Fig. 8. Covered reaction-vessel from W/1020 (Sung).

W/889 (p. 2*b*) mentions five types of *ting*:

> "One is called *chin ting*[96] (gold vessel), the second is called *yin ting*[97] (silver vessel), the third is called *thung ting*[98] (copper vessel), the fourth is called *thieh ting*[99] (iron vessel) and the fifth is called *thu ting*[100] (pottery vessel)".

Figure 7 taken from the Sung text W/1020 (ch. 72, pp. 10*a*, 10*b*) shows a *chin ting*[96] (gold vessel). The text also gives the following description:

> "According to rule the *ting* measures 1 ft. 2 in. in height and weighs 72 oz. The number is nine (alternative translation: 'there are nine of them').

[b] We depart here from the translation made formerly by Wu & Davis (41).

The inner circumference is 1 ft. 5 in. The *ting* is supported by legs so that it stands two and a half inches above ground. The base has a thickness of 2 in., while the body is one and a half inches thick. It has a capacity of three and a half *shêng*[101] (approx. 100 cu. in.) when filled to a depth of 6 in. The cover is 1 in. thick and the ears are one and a half inches high".

In the same chapter (p. 24*b*) of this text we find another diagram of the *ting* (Fig. 8). It has a lid and the decorations are more elaborate.

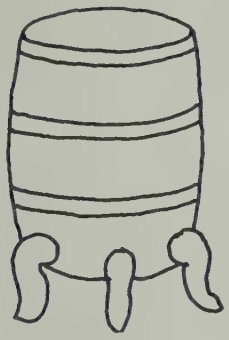


Fig. 9. "Suspended womb" reaction-vessel from W/1054 (Yuan).

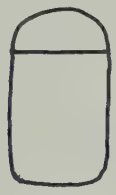


Fig. 10. Aludel from W/904 (Sung).

The Yuan text W/1054 (p. 8*b*) gives an illustration (Fig. 9) of the *hsüan thai ting*[102] (suspended womb vessel) with the following description:

> "The *ting* has a circumference of 1 ft. 5 in. and is hollow inside for 5 in. It is 1 ft. 2 in. high like a *phêng hu*[77] pot. . . . It also symbolizes the human body. It consists of three layers corresponding to the Three Powers (*san tshai*[103])—Heaven, Earth and Man. The upper and the middle section of the *ting* are connected by the same vertical passage. The upper, middle and lower sections must be evenly set. (The *ting*) is put into a *lu*[76] (stove) to a depth of 8 in. or is suspended inside a *tsao*[68] (combustion-chamber) so that it does not touch the base. Hence the name *hsüan thai* (*ting*)[102] (suspended womb vessel). It is also called the cinnabar vessel—*chu sha ting*[104]. In Chang Sui's[87] annotations it also receives the name *Thai I shen lu*[105] (magical vessel of the Great Unity)"[c].

From the above quotations we can see that sometimes it is difficult to distinguish between a *ting* (reaction-vessel) and a *lu* (stove) as the two terms may refer to the same apparatus.

In all the examples so far mentioned the *ting* has been represented by cauldron-like forms with three legs, i.e. tripods. However, the legs were often omitted, for one may see in Chinese museums (e.g. at Sian and at Chêngchow)

[c] Tshao Yuan-Yü (34) confused the *hsüan thai ting*[102] with the *yen yüeh lu*[85] by calling the former *wei kuang lu*[107] and the latter *Thai I shen lu*[105].

large cast-iron cauldrons about 1 ft. diameter at the mouth dating from the Han period and almost certainly used for alchemical or technological preparations. Moreover, as we have pointed out, the word *ting* has a wider meaning. For example, no legs are attached to the *hun tun ting*[106] (chaos vessel), taken from the Sung book W/904 (p. 6*b*), and shown in Fig. 10. In fact, it has now become plainly a reaction-chamber.

In one method of *yang huo*[108] (conserving the glowing fire) we shall see that fire was applied above and around the reaction-chamber, below which was placed a receiver containing water, and that the space inside the combustion-chamber was packed with ashes. In another method described in W/912, a Thang text, we find that fire was applied all round the reaction-vessel. Fig. 11 (from ch. 1, p. 9*b* of this text) shows the *lu* (stove) with a *ting* (vessel) and how the glowing fire was conserved. The fuel used in this case was charcoal.

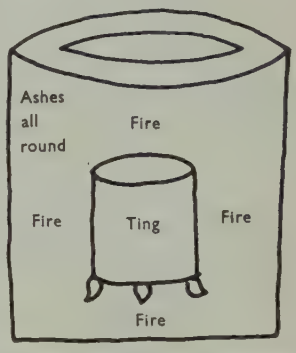


Fig. 11. Furnace and reaction-vessel from W/912 (Thang).

Next, we have what was known as the *kuei*[94] (box, casing, container) the function of which was rather similar to that of the *ting* (reaction-vessel),

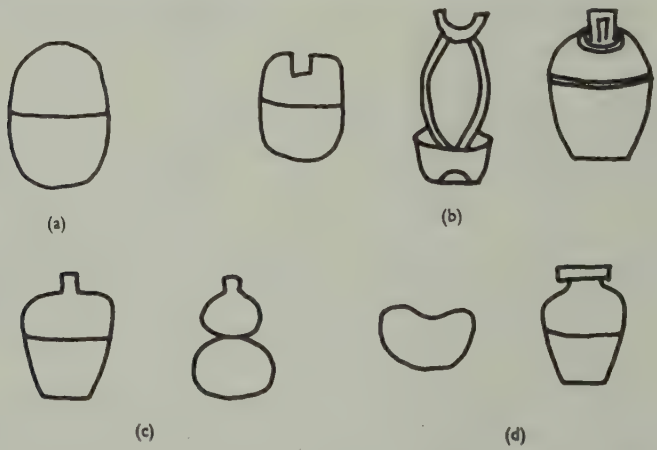


Fig. 12. Types of aludels and reaction-vessels from W/939 (Sung).

because within the *kuei* was placed the reaction-chamber. Sometimes the *kuei* itself formed the reaction-chamber. Several types of *kuei* are illustrated in W/939. In Fig. 12 (*a*) is taken from p. 4*b*, (*b*) from p. 5*b*, (*c*) from p. 8*b* and (*d*) from p. 10*b*. Some of the *kuei* appear to be containers pure and simple.

The same text (pp. 14*b* and 15*a*) also mentions the following types of *kuei*:

huang-ya kuei[109] (yellow sprout casing).
pai-hu kuei[110] (white tiger casing).
hei-hu kuei[111] (black tiger casing).
huang kuei[112] (yellow casing).
hsüan-chen kuei[113] (suspended needle casing).
li-chih kuei[114] (immediate fixing casing).
san-chih kuei[115] (rice cake casing).
yung-chhüan kuei[116] (bubbling spring casing).
thien-sêng-huang-ya kuei[117] (natural yellow sprout casing).

Further accounts of other types of *kuei* are given in W/946. Fig. 13 is an example taken from this text (ch. 1, p. 3*a*). In the same work (ch. 2, p. 15*a*) we also find a description of the *phi kuei*[118] (arsenic casing):

> "Make *tzu ho chhê*[119] (lead) into powder. For every ounce of *phi mo*[120] (arsenic powder) use one and a half oz. of *ho chhê*[121] (lead) powder. After stirring and mixing they are put into a *kan kuo*[122] (crucible)[d]. Begin with a gentle fire and gradually increase its intensity. When calcination is over use the residue to make a *kuei* (casing). This is most useful for preserving (*yang*[123]) *fên shuang*[124] (calomel)".

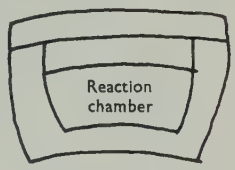


Fig. 13. Reaction-chamber from W/946 (Sung).

In another example mentioned in the same treatise (ch. 7, p. 11*a*) a *kuei* was made from *chhing yen*[125] (blue salt; rock salt), *pai yen*[126] (white salt) and the juice extracted from arrowroot. This recipe must originally have included a refractory clay. It is interesting in this connection that accounts of blast furnaces in late mediæval China generally mention "salt" as well as clay, lime and sand. The suggestion is elsewhere made that gypsum (calcium sulphate) was really meant in these cases, for among its traditional names are *yen chen*[127] ("salt's pillow") and *yen kên*[128] ("salt's root"), both probably derived from stratigraphic relationships[e]. Gypsum is still used in the making of mortar and cement. Unless certain characters have dropped out of the text, the bald statement we have here may have been meant to deceive the uninitiated while being perfectly comprehensible to those with alchemical training. Other examples of *kuei* are given in W/912, an important Thang text.

(4) *The Closed Reaction-Vessels or Bombs* shen-shih[72] (*magical reaction-chamber*) *and* yao-fu[90] (*vessel composed of two crucible-like bowls placed mouth to mouth*)

Besides the more open crucible or bowl-like forms of reaction-vessels many kinds of closed containers were employed. They correspond no doubt to the

[d] Also called *khan kuo*[129].
[e] Needham (25), vol. 5, pt. 1.

aludels of Arabic-Western alchemy. In some cases it is likely that when they were made of metal pressures considerably higher than atmospheric were generated in them; in other cases they were used for sublimation. Fig. 14 taken from W/907 (ch. 2, p. 2*a*) illustrates one of these reaction-chambers, as used in the Sung.

Fig. 14. Reaction-chamber from W/907 (Sung).

Another important closed vessel was the *yao-fu* (vessel composed of two crucible-like bowls placed mouth to mouth). The following is an account of its construction taken from W/874 (pp. 14*a* and 14*b*), a text written probably in the Liang period (+6th century):

"Method of making a *yao-fu*:

> The lower iron bowl (*thieh-fu*[130]) has a capacity of one peck (*tou*[131]), a diameter of 9 in. and a height of 3 in. At the base, which comes in contact with the fire, the thickness is 0·8 in., but around the four sides the thickness is 0·3 in. The upper and lower bowls are of equal thicknesses. The base is flattened. The flange all round is one and a half inches wide and 0·3 in. thick; it is also flattened. The two handles at the side are three inches long and three and a half inches wide; they are situated above the flange. The upper bowl (i.e. the cover) is made of pottery (*shao wa*[132]). It has a diameter of 9·4 in., a height of 8 in. and a thickness of 0·3 in. The cover thus has a greater curvature (than the lower bowl). Its flange is also made flat. The *yao-fu* is used for the preliminary treatment of the ingredients and hence its size. After the ingredients have become refined they should be transferred to a *hsiao-fu*[133] (small vessel) (which measures) six inches across at the mouth and two and a half inches in height. Besides these the shape and other dimensions (of the lower bowl) are the same as (those for the *yao-fu*). For the cover the diameter is 6·2 in. and the height 6 in. Besides these the shape and other dimensions do not differ from those of its predecessor".

A conjectural diagram of the *yao-fu* is given in Fig. 15.

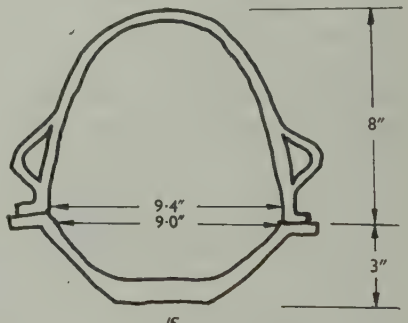


Fig. 15. Reconstruction of the *yao-fu* 'bomb' from W/874 (Liang).

The dimensions of the *yao-fu* were by no means standardised. For example different values are given in the description of the *yao-fu* in the Sung text W/1020 (ch. 68, p. 27*a*).

The description of the *yao-fu* suggests the use of close-fitting surfaces by the Chinese alchemists. Iron bowls with smooth lapped edges were produced early in China. Li Kao[134], a Thang prince

(+752 to +820), experimented with bowls and plates fitting so well that no air could enter and displace liquids contained within them. Li Yuan[135] used iron bowls ground very smooth at the edges. Similar experiments were carried out by Jen Shih-Chün[136] about +780. The context of this was the search for accuracy in tuning musical instruments by filling sets of precisely fashioned vessels with different amounts of water; for further details see Needham (25)[f]. But in due course a much more sinister development occurred when the first gunpowder bombs were made from these opposed hemispheres or "coquilles" in the +12th and +13th centuries. This story will be told in the same work[g].

(5) *Steaming Apparatus, Water-Baths, Condensation Vessels and Cooling Jackets*

At this point our exposition must commence in prehistoric times when alchemy and chemistry had not yet developed from the techniques of cooking. During neolithic times (before −1500) the Chinese people invented a peculiar type of vessel, the *li*[137], in shape like a substantially built pottery jug, with or without handles but always having the bottom running smoothly into three hollow, bulbous legs, often strikingly resembling breasts. The purpose of this cooking-pot was presumably to bring the food into closer contact with the heat of the fire rather than to be able to cook three different foods separately at the same time. Fig. 16*a* shows two characteristic *li* of pottery (after de Tizac); abundant specimens are preserved in museums all over the world. The shape continued into the Shang and Chou periods made in bronze instead of pottery. Sometimes the vessel may have a fixed cover with a hole for filling and a spout for pouring out. There is reason for believing that the tripod cauldron (*ting*) originated by the collapsing of the bulbous legs of the *li*.

As is well known, the typically Chinese method of making bread from cereals throughout the ages was steaming and not baking. And so the *li* generated a form of double vessel in which it was surmounted by a simple pot having holes in the bottom through which the steam could mount to cook the dough. While we must not here go too far into the typology of these vessels, it should be said that they are distinguished by whether the top vessel is separable from the bottom one or not[h]. Steamers of the former type are known as *tsêng*[138], those of the latter type as *hsien*[139] or *yen*[139]. Again the early crude pottery forms were perpetuated in much more elegant bronze, and with free ring handles, during the Shang and Chou periods. In the pottery stage the *tsêng*[138] are much more common than the *hsien*[139]; Andersson in 1947 found upper vessels with perforated bottoms obviously intended for placing over *li* with flanged mouths (see Fig. 16*b*). Examples of these are to be seen today in

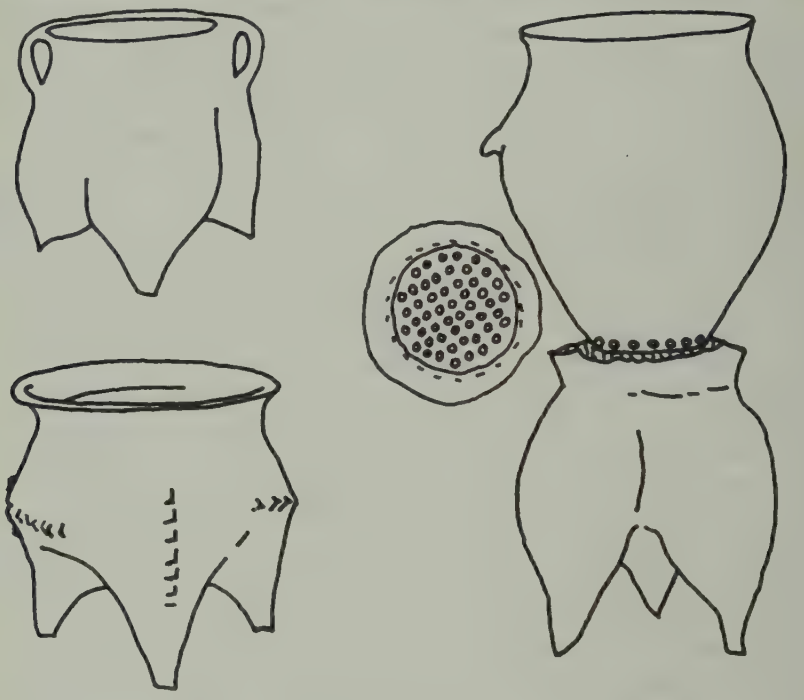
[f] Vol. 4, pt. 1.

[g] Needham (25), vol. 5, pt. 1.

[h] See e.g. Tzu Chhi (35) in *Wên Wu Tshan Khao Tzu Liao*, 1958, and Willetts (39), vol. 1, pp. 125 ff.

Chinese museums[5] one for instance is in the Archaeological Laboratory of Academia Sinica at Sian.

A Shang example of a bronze *hsien* from about −1300 is seen in Fig. 17*a*, and an early Chou type in Fig. 17*b*[i]. Whether the bottom of the upper vessel



(a) (b)

Fig. 16. (*a*) Pottery *li* vessels, (*b*) pottery *tséng* steamer; all from the −3rd millennium.

is perforated or whether there is a removable plate (when the whole vessel is in one piece) the grating takes a great variety of forms, round holes, slits, crosses, etc., etc., in multifarious patterns. One example of a bronze *ting*[70] which might have been the bottom of a *tséng*[138] from about −500 (in the Shantung Provincial Museum at Chinan) has a very well moulded water-seal rim round the top of the lower bulbous-legged vessel.

By the Chhin and Han there are many literary references to these vessels. For example, in the *Chou Li*[140] (Record of Institutions of the Chou Dynasty), a text of perhaps the −4th, certainly of the −2nd, century, the *tséng* is mentioned together with its close relation the *hsien* steamer[j]. Many of these bronze

[i] The former after Bushell (1914), the latter after Bishop (1956).

[j] Ch. 12, p. 7*a*; Biot's translation, vol. 2, p. 537.

Fig. 17*a*. A bronze *hsien* from the Shang kingdom, ca. – 1300 (from Bushell).

Fig. 17*b*. A bronze *hsien* from the early Chou period, ca. – 1100 (from Bishop).

vessels dating back to the Shang, Chou and Han periods still exist today in museums and private collections.

Han funerary stoves of pottery or bronze frequently have a special hole in the top designed to take the lower vessel of a *hsien* or *tsêng* resting upon a flange around its middle. One of these in the Archaeological Institute of Academia Sinica at Sian has a set of three top vessels, one with coarse holes for steaming, another with fine holes, and a third with no holes at all for water-bath heating.[k] Since these date from between the −2nd and the +2nd century

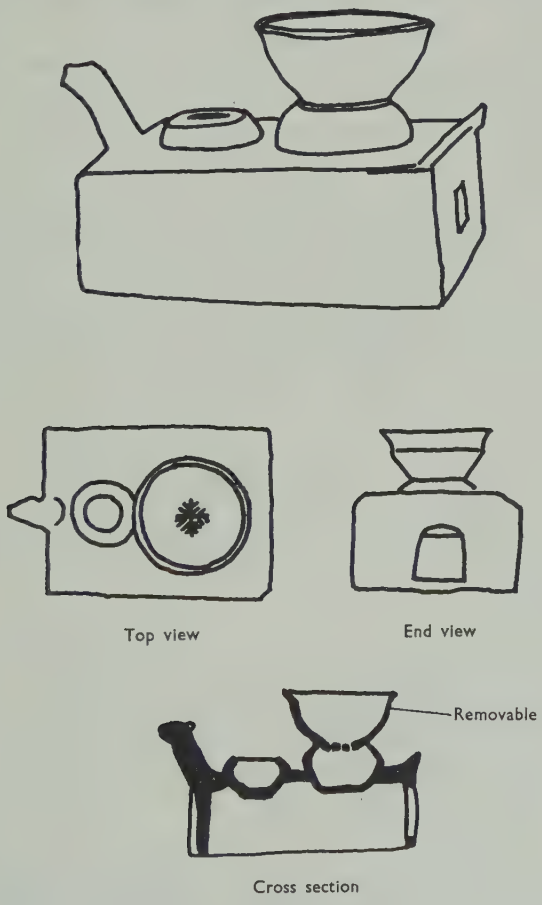


Fig. 17*c*. Tomb-model of stove and steamer from Chhangsha (Former Han).

[k] Other examples from the −1st century are illustrated in the Report of the Excavations at Chhangsha (*Chhangsha Fa Chüeh Pao Kao*, Peking, 1957, pp. 100, 101, pl. 53). We give one as Fig. 17*c*.

they parallel, if indeed they do not anticipate, the invention of the water-bath (the "bain-marie") by Mary the Jewess at Alexandria[l]. Another example, in the Kansu Provincial Museum at Lanchow, has a slit-perforated steaming basin on three legs to fit into a larger basin on a stove, and above that again a smaller basin on three legs with a solid bottom for pure steam heating. The close connection between all these cooking utensils and the equipment of the alchemists' laboratory is obvious.

The *tsêng* found a fiercer use in metallurgy (especially non-ferrous) when it took the form of two superimposed crucibles, the upper one having a perforated bottom. From the ingredients placed above, the molten metals descended below when the heating was sufficient, leaving the less fusible oxide scoriae and slag in the upper vessel. The whole was known in Syriac as the *bot-bar-bot* ("the crucible and the son of the crucible") a term which got into Latin as the unintelligible *botus barbatus*[m]. It was used for preparing alloys of copper, lead, iron, tin, arsenic, etc., some of which closely resembled silver. More than a hint as to the origin of this apparatus is contained in the untitled +9th to +11th-century Arab-Syriac alchemical treatise translated by Berthelot & Duval, which says, "it will come down to form an ingot like Chinese iron". This *khār-ṣini* was either metallic zinc or the famous alloy paktong (*pai thung*[226]), a mixture of copper, zinc and nickel which had been made in China for many centuries before it became known in the West. One of the earliest references to it may be the *Kuang Ya*[227] dictionary by Chang I[228] ca. +230. Its appearance in the Arabic Jābirian corpus of the +9th and +10th centuries is one of the pieces of evidence pointing to Chinese influence at that time. But this may have been exerted still earlier, as another, purely Syriac, treatise, also translated by Berthelot & Duval, dating from the +7th to +9th centuries and closely related to the earlier Greek texts, speaks of taking "two amphorae, one being pierced with holes".

The texts classify *ting* into two types—*huo-ting*[141] (heating reaction-vessel) and *shui-ting*[142] (cooling vessel). For *huo-ting* heat was applied externally, sometimes all round, sometimes only underneath. This is in effect the *ting* already described. But the *shui-ting* (cooling vessel) contained water and could be used in conjunction with a *huo-ting*. According to its position, it brought about local cooling within the *huo-ting* to facilitate sublimation and condensa-

[l] There are, of course, no grounds for this attribution other than the modern name itself and an appeal to immemorial tradition. What Berthelot (2), pp. 146 ff., labelled as forms of the "bain-marie" seem much more like perforated stoves under the kerotakis. On the other hand, an enigmatic diagram (p. 141), also from MS. Marc 299, with no accompanying explanation in the text, has a bath labelled *pontos*, "the sea", but it seems to be part of the cooling arrangements for the condenser of a still.

[m] Berthelot & Duval (44), pp. 58, 149.

tion; or it prevented the rise of the temperature of the reactants above boiling water and steam level. Fig. 18 taken from W/908 (ch. 1, p. 25*a*), a text perhaps of the Chin dynasty (+265 to +420) indicates diagrammatically the position of the *shui-ting* as a condenser in one of the alchemical processes. This arrangement brings us very near to the beginnings of distillation on which we shall have more to say shortly.

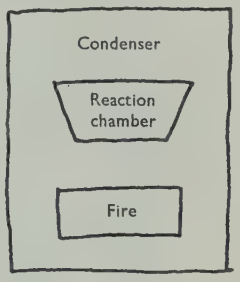


Fig. 18. Diagram of furnace with condenser from W/908 (Chin).

W/907 describes the water-bath as used by the Sung alchemists under the name *huo-phên*[143] (fire-bowl), which was simply a basin with a three-legged support containing charcoal. Fig. 19 taken from this text (p. 4*a*) purports to show a fire-bowl together with what is called a *tsêng* though actually the stove only is shown and the steamer is left to the imagination. The text describes the apparatus as follows:

> "Below (the steamer) is placed a *huo-phên* (fire-bowl). Bricks are laid until level. On top (of the fire-bowl) is built a *tsêng* (steamer) 1 ft. 5 in. high and 1 ft. 2 in. in diameter. Four openings are made in the middle facing north, south, east and west (*tzu*[144], *wu*[145], *mao*[146], *yu*[147]) and in communication with the mouth of the steamer at the top. These five openings enable fire to be emitted from the mouth at the top. (The

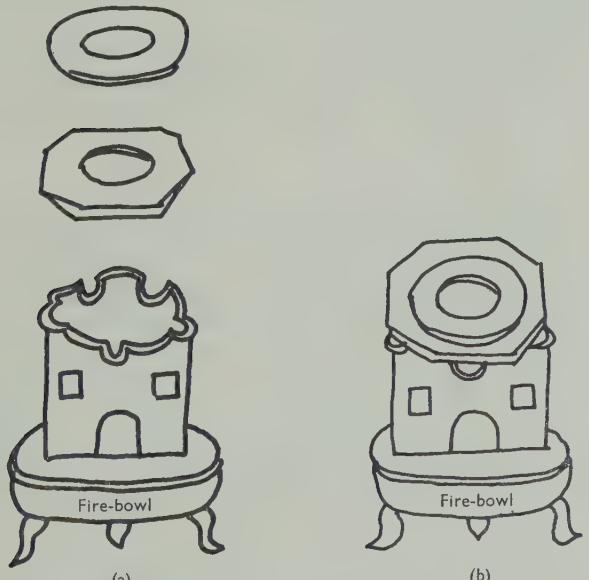


Fig. 19. Stove and steamer from W/907 (Sung).

walls) should be thick. The mouth for the steamer is circular, 5 in. in diameter. A piece of square tile is cut into two and placed squarely on the heater, while a second piece with side measuring 1 ft. 2 in. is put over the top. (The apparatus) uses both water and fire. The *tan ting*[148] (reaction-vessel) is suspended at the centre (presumably in the steam)".

In the alchemical books of the Sung period very peculiar and complicated combinations of condensers and water-jackets are described. How the different parts of the apparatus were assembled for these more complicated experiments can be seen most conveniently from W/907. This says (ch. 1, p. 1*a*):

"Method of constructing the *shen-shih*[72] (magical reaction-chamber):

Eight ounces of pure gold (lit. full-coloured gold) are cast into a *hun-tun thai-yuan ho-tzu*[149] (chaos womb-shaped closed vessel; reaction-chamber), which is shaped like an egg or a round ball. Then take another ounce of pure gold to make a tube (*chhi-kuan*[150]) with a bore the size of the hole in a coin. The length of the tube should project beyond the reaction-chamber by about half an inch. (The capacity of) the reaction-chamber should be just sufficient for holding the *tan-phi*[151] (elixir embryo, i.e. the ingredients), and should be neither too big nor too small. After the ingredients are introduced the joints are sealed by means of *chhih-shih-chih*[152] (red bole clay) mixed with *chin-thu*[153] (earth) and vinegar and left to dry.

Eight ounces of silver (*pai-chin*[154]) are used to make a *shui-hai*[155] (a funnel-shaped reservoir). The lower end is set on to the opening of the *ting* (reaction-vessel) and goes down to a depth of about 2 in. When the two are found to fit, the lower end of the *shui-hai* reservoir is connected to the gold tube (*chhi-kuan*[150]) so that water can flow (down into the latter). The joint is firmly sealed by means of *chhih-ni*[156] (a lute or sealing mixture, possibly of red bole clay and mud) and left to dry before water is poured in.

The *wai-ting*[157] (outer vessel):

This is made of pottery. Its capacity should be just sufficient for inserting the reaction-chamber and 2 lb. of silver (*pai-chin*[154]) and must be neither too spacious nor too narrow. If it is too large the space can be filled in using yellow earth mixed with vinegar and left to dry. Then half a handful of silver is put in and adjusted until it is packed and level before the gold reaction-chamber is inserted. Silver is again put over the top until (the reaction-chamber) is covered up. A paper ring is put over the reaction-chamber to mark the position for the *shui-hai* reservoir. After filling up (the *ting*) with silver, the silver *shui-hai* reservoir is put in position through the hole as marked by the ring. (The *ting*) is then shaken up until everything is properly packed. The outside has to be tightly sealed before (the vessel) is suspended inside the combustion-chamber".

Figure 20 taken from this text (ch. 2, p. 2*a*) illustrates the reaction-chamber (*b*) and the *shui-hai* reservoir (*a*) and also how they were assembled inside the

huo-ting[141] (heating reaction-vessel) (*c*). The caption of the diagrams is rather similar to what we have just read. It says:

> "Eight ounces of pure gold are cast into a *hun-tun chi-tzu shen-shih*[158] (magical chaos egg-shaped reaction-chamber). Again one ounce of gold is used to make a water-tube (*shui kuan-tzu*[159]), the lower end of which is closed and does not allow water to pass through. It is about 4 in. long and is inserted down to the base of the *hun-tun ho*[160] (chaos closed vessel; reaction-chamber). The top end is attached to the *shui-hai* reservoir, which is made of eight ounces of silver. The joints are all tightly sealed with (*chhih-shih*)-*chih*[152] (red bole clay) and *fan*(-*shih*)[161] (alum) and allowed to dry. The portion (of the tube) inside the reaction-chamber is filled with water".

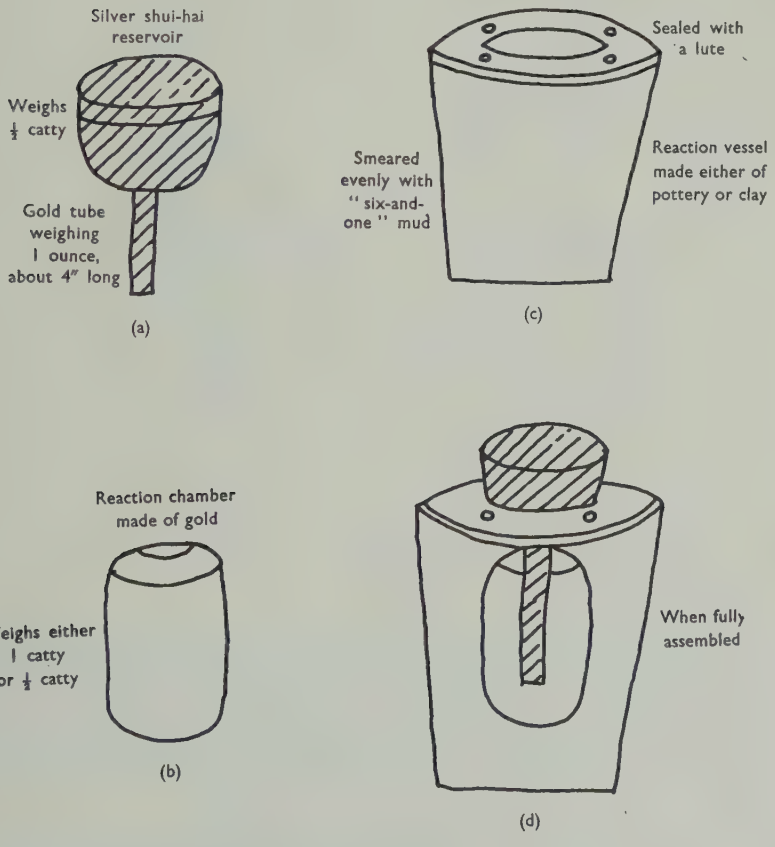


Fig. 20. Water-cooled reaction-vessel from W/907 (Sung).

The text then describes the process that followed after the ingredients were introduced. It says:

> "The joints (of the reaction-chamber) are tightly sealed. It is then put into a pottery vessel (*thu-ting*[100]) and the space inside filled with silver beads (*yin-chu*[162]) so that no gap is left. After the silver *shui-hai*

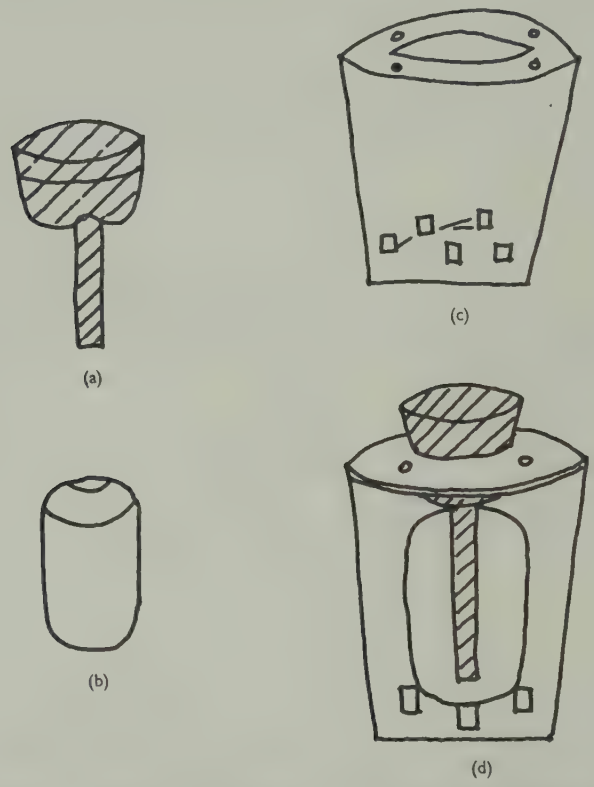


Fig. 21. Another water-cooled reaction-vessel with central cooling column from W/907 (Sung).

> reservoir is set on top the outside is smeared (with a lute) to a thickness of a finger's width. After drying for half a day (the vessel) is suspended inside the combustion-chamber. Fire is applied below and round all sides (of the vessel). At first 5 lb. of charcoal are used, and when more than half that amount is burnt another 5 lb. of charcoal are needed. These are to be added twice or thrice within the period of one day and night . . .".

Another example from the same text (ch. 2, p. 18*a*) is given in Fig. 21. What is particularly noteworthy about these pieces of apparatus is the large

vessel of water at the top of the system, for it corresponds exactly with the position of the main condenser basin in the characteristic East Asian type of still (see below, p. 92).

The purpose of the *shui-hai* reservoir and the attached tube must have been to exert a thermometric control by ensuring the presence of water at boiling

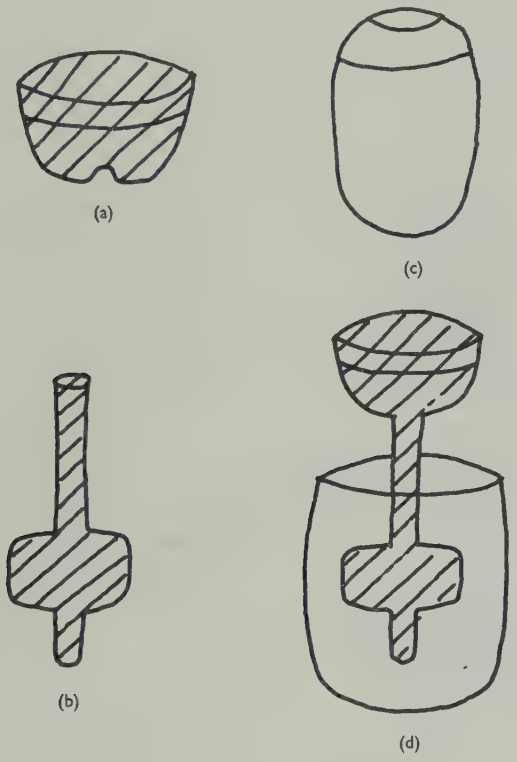


Fig. 22. Central cooling column with bulb from W/907 (Sung).

temperature isolated from the reactants. The insertion of a blind tube into the centre of the reaction-chamber meant that the reactants would be cooled centrally. We find many other approximations to constant-temperature technique in the same text. The first elaboration was to introduce a bulb in the central cooling column, as in Fig. 22 (ch. 2, p. 16*b*). The next thing was to introduce two bulbs as shown in Fig. 23 (ch. 2, p. 10*a*). Still more complicated is the system given in the same chapter (pp. 5*b* and 6*a*) where the central tube connects the upper reservoir or condenser with a water space below built in to the side-walls of the reaction-chamber (Fig. 24).

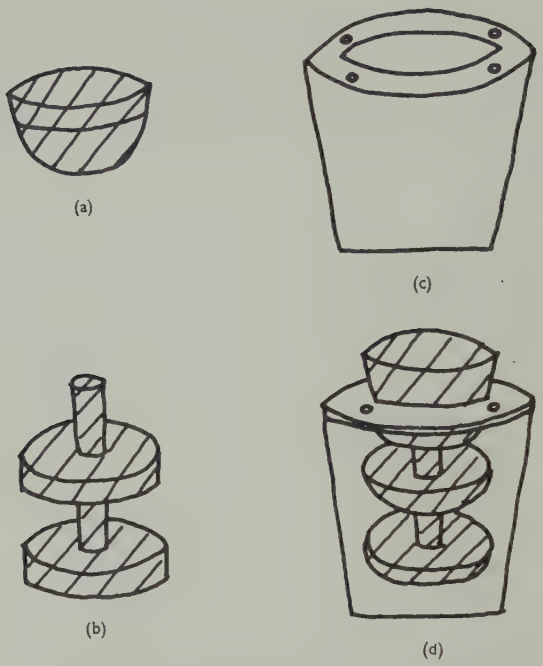


Fig. 23. Central cooling column with two bulbs from W/907 (Sung).

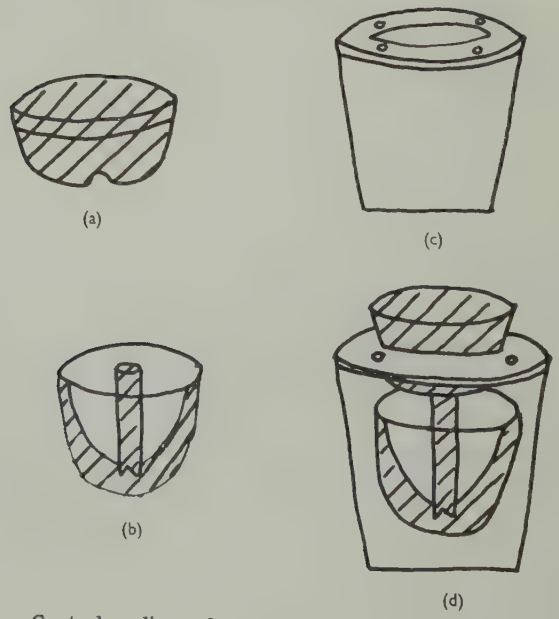


Fig. 24. Central cooling column and water-jacket from W/907 (Sung).

Several other types of cooling system related to those already described and taking the form of veritable water-jackets are given in the same text and are shown in Figs. 25 to 29. One sees how the aim was to increase the cooling surface. It was evidently a prime concern of the +13th-century alchemists to control the temperature of their reactants and prevent it from rising too high.

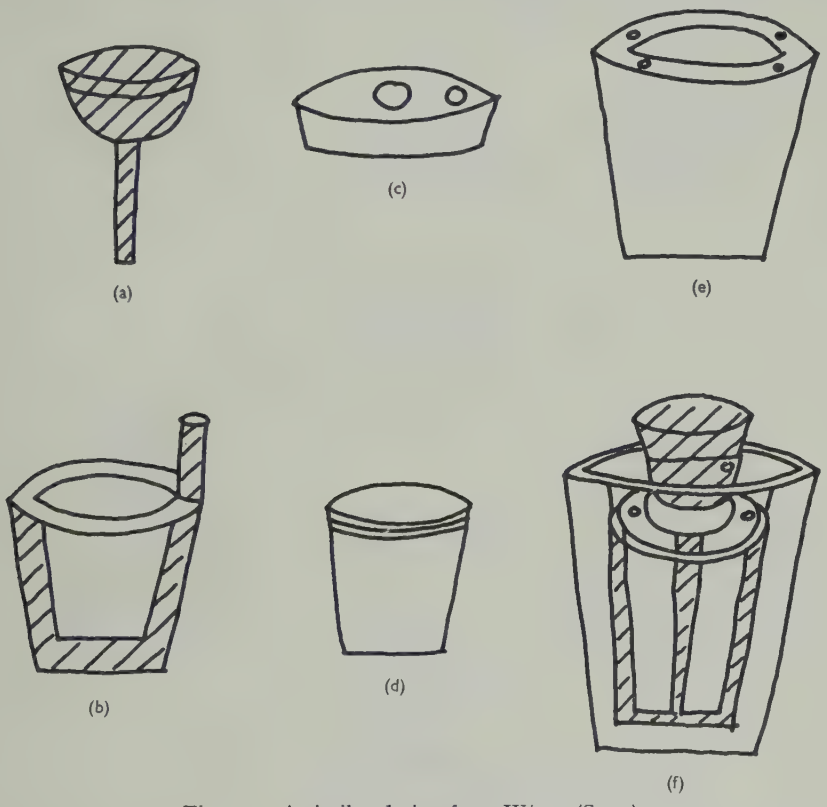


Fig. 25. A similar design from W/907 (Sung).

By varying the extent of the water-jacketing they could choose any desired temperature for their reactants. Fig. 25 (ch. 2, pp. 8*b*, 9*a*) shows a water-jacket with an upper filling tube at one side. Fig. 26 (ch. 2, p. 7*a*) shows another version of the external water-jacket. A water-jacketed hood is seen in Fig. 27 (ch. 2, pp. 11*b*, 12*a*) forming a more complicated type of condenser. Fig. 28 (ch. 2, p. 13*b*) shows a complete water-jacket. In the *san-shui-kuan*[163] (triple water-pipe) reaction-vessel water-cooling was applied externally by means of three pipes. This is shown in Fig. 29 (ch. 2, pp. 3*b*, 4*a*).

(6) *Sublimation Apparatus*

The simplest form of vessel for this purpose would be a pot with a removable lid, heating being applied locally at the bottom so as to allow for the condensation of the volatile substance on the under surface of the lid, whence it would be easily removed. Fig. 30 shows what is called a "mercury vessel"—*hung-ting*[164]—in W/905 (ch. 2, p. 3*b*), a Sung book. It was certainly used for sublimation. The sublimate adhering to the cover—the *yin-kai*[165]—was collected at

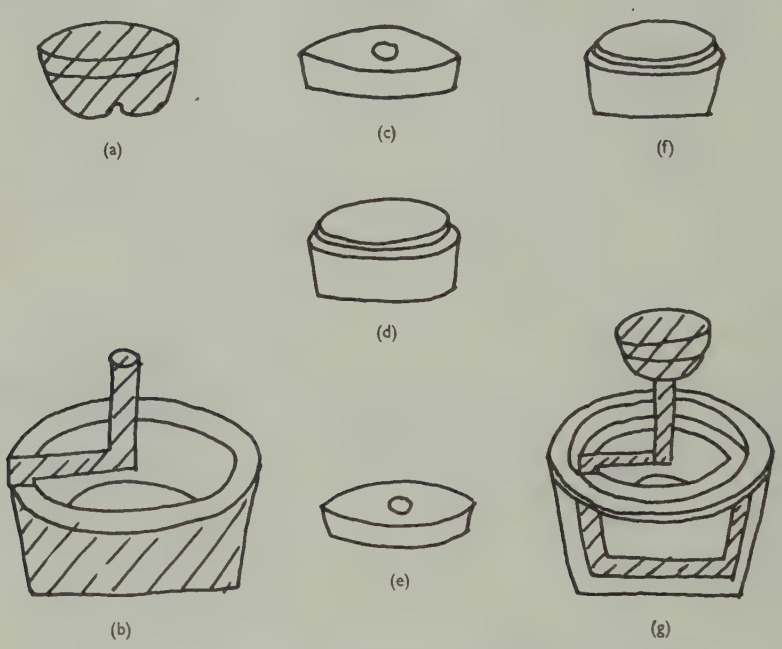


Fig. 26. A further water-jacket design from W/907 (Sung).

the end of the operation by scraping with a feather. It would seem that the *yao-fu*[90] types of vessel (see p. 70 above) were commonly used for this operation. Tripod pots of bronze from Chou and Han with removable lids are quite common in museums; they are often spherical in shape, and sometimes the lids have ring handles as if for attaching chains for lifting.

If we are right in our interpretation, one of the most interesting of all ancient pieces of Chinese chemical apparatus was used for sublimation. During the second world war (in 1943) the Institute of Cultural Studies of the University of Nanking (then located at Chhêngtu, Szechuan) exhibited a remarkable bronze

self-named from its inscription as a "rainbow vessel" (*kung têng*[166])[n]. We reproduce it[o] in Fig. 31 *a,b*. Above a round tripod vessel in the form of a flattened sphere there is a cylindrical compartment with sliding walls capped by a hemispherical dome. Two tubes of ample lumen arise one on each side from the lower vessel and join at the top at the crown of the dome. The upper

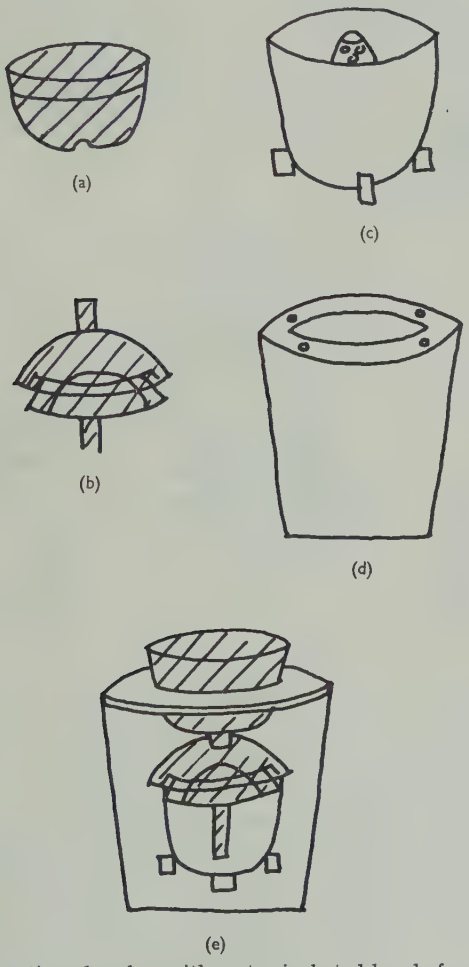


Fig. 27. Reaction-chamber with water-jacketed hoods from W/907 (Sung).

[n] Normally the word rainbow has the "insect" radical, and the lexicographers' meanings for *kung*[167] are the iron bearing of a chariot hub or an ornament worn by women at their belts. But the present context is unique. Similarly *têng*[168] is the word later used for a stirrup, not a lamp or vessel.

[o] By the kindness of Dr. Li Hsiao-Yuan.

halves of the tubes and the dome are removable after which the central cylinder, which has no direct communication with the bottom, can be lifted off by the side handle. The inscription says *Yen Ong Chu thung kung têng i chü*[169], i.e. "One rainbow vessel belonging to Old Master Yen". The object which was found in a tomb at Chhangsha, Hunan, is considered to be of Hou Han date (+1st or +2nd century).

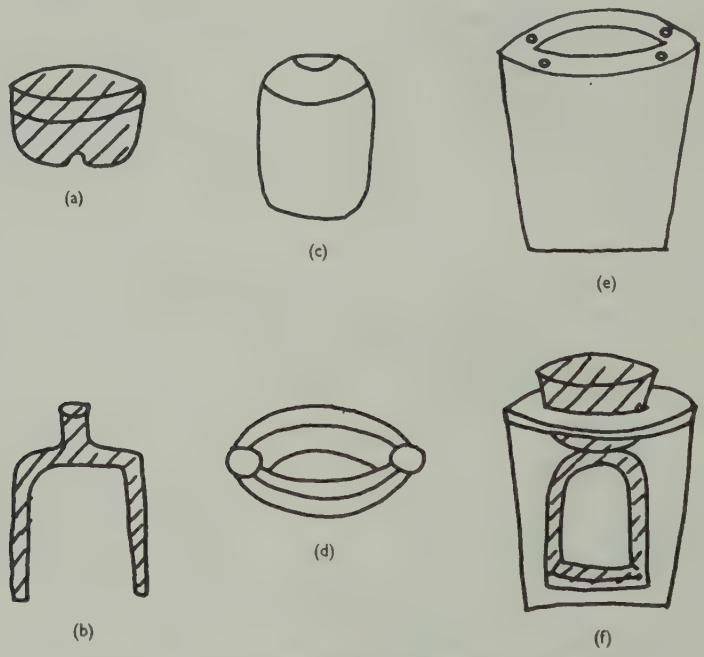


Fig. 28. Complete water-jacket from W/907 (Sung).

More recently, further excavations at Chhangsha have brought to light another example (see Fig. 32), in dimensions closely similar to the former (e.g. height about 34 cm.), but in date somewhat earlier (−1st century)[p]. It has no inscription. The authors of the report regard the object as some kind of lamp, but this is hard to believe since no space exists for light to be irradiated. We much prefer the view that substances to be volatilised were placed in the lower part of the vessel, so that the vapour would ascend through the tubes and condense in the upper compartment, perhaps with the assistance of cold wet rags outside. The fact that according to the authors of the report some waxy substance was found in the upper compartment when the vessel was excavated might surely mean that a mercury ointment was being compounded.

[p] See *Report*, 1957, p. 115.

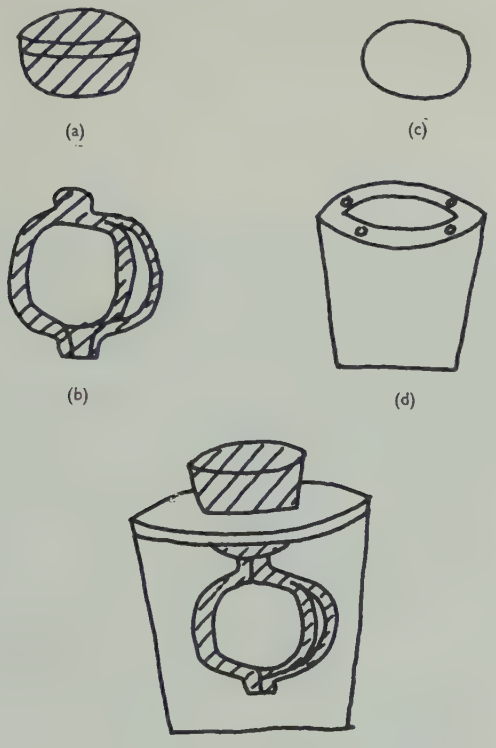


Fig. 29. Peripheral cooling of a reaction-vessel by means of three pipes, from W/907 (Sung).

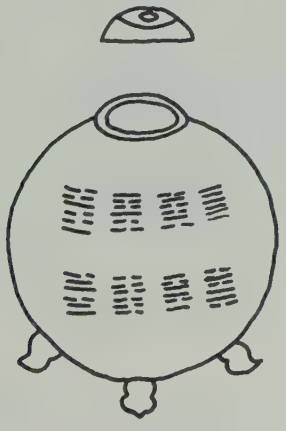


Fig. 30. Sublimatory from W/905 (Sung).

The only other examples known were illustrated long ago in an antiquarian work, the *Hsi Chhing Ku Chien*[170] (Catalogue of Ancient Mirrors and Bronzes

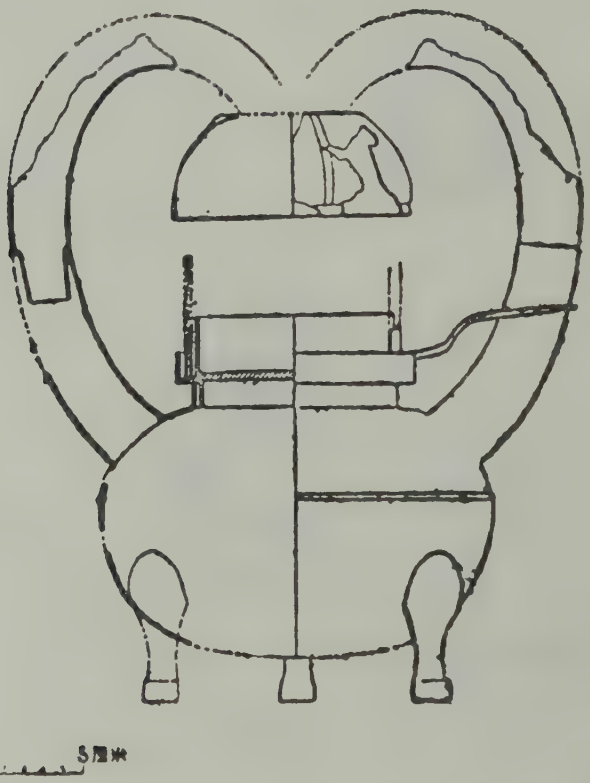


Fig. 32. Another "rainbow vessel" recently excavated at Chhangsha, ca. — 1st century, Former Han.

of the Imperial Collection in the Library of Western Serenity) by Liang Shih-Chêng[171] in +1751 (ch. 30, also Second Supplement, +1793, ch. 13, pp. 33*b*, 34*a*). We reproduce the latter here (Fig. 33); it will be seen that it has lost its central cylindrical walls. The editors called the first one a *têng*[168] but this one a *ting*[172], i.e. a hot-plate[q].

[q] This was one of the most ancient meanings of the word, which later came to mean an ingot and eventually an anchor.

Fig. 31*a*. The "rainbow vessel" (*kung teŋ̂g*) of the University of Nanking (ca. + 1st century, Later Han), probably used for sublimation, front view.

Fig. 31*b*. The "rainbow vessel", side view.

(7) *Distillation and Extraction Apparatus*

The first Western description of the process of obtaining metallic mercury from cinnabar by the method of sublimation is generally attributed to Dioscorides (c. +50) who said that cinnabar was heated on an iron saucer contained in a pot and covered by another pot[r]. Throughout history cinnabar was one

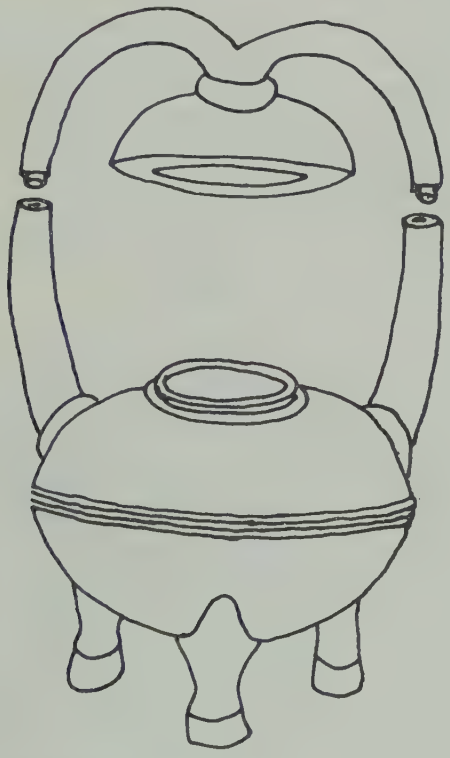


Fig. 33. "Rainbow vessel" from the imperia collection, Han period.

of the most important raw materials used by the Chinese alchemists for the preparation of elixirs. Although we do not know exactly when they first began converting cinnabar to mercury we have evidence to show that they knew about this process by the beginning of the Han (—2nd century). The *Shen Nung Pên Tshao Ching*[173] (Pharmacopoeia of the Heavenly Husbandsman) states

[r] *Materia Medica*, V, 110. See Taylor (33), p. 52; Forbes (10), p. 17. The method was of course described and figured in detail by Agricola in +1556 (Hoover & Hoover ed., pp. 426 ff.).

clearly that cinnabar can be converted into mercury[s]. What may be the earliest reference is in the *Huai Nan Wan Pi Shu*[174] of ca. −120, which makes the same statement[t]. In the previous section we have seen the use of various closed vessels with removable lids in ancient China for this simple process.

(*i*) *Destillatio per descensum.*

The other ancient or early mediæval method was "destillatio per descensum". A number of flask-shaped pots were filled with cinnabar ore, plugged loosely with moss, and inverted over a second series of pots buried in the earth. Under the influence of heat from above the mercury liberated by oxidation dropped down into the lower receivers while the sulphur dioxide escaped through the porous walls of the "retort". We do not know when this process was first used in Europe. However, it clearly appears in W/884 (p. 1*b*), a text of Thang period (+7th to +10th century). This says,

Fig. 34. Bamboo tube for descensory distillation, from W/884 (Thang).

> "From 16 oz. of *kuang-ming sha*[179] (a high-grade cinnabar) 14 oz. of mercury can be extracted[u]. The method is to make a pipe from bamboo, which is cut until three joints are left. Pellet-size perforations are made, or small holes about the size of the thick end of a chopstick, in the middle diaphragm to enable the mercury to flow downwards. At first two layers of wax-paper are put over the middle diaphragm. Then the cinnabar is finely ground and introduced into the (upper section of the pipe, the uppermost diaphragm being used as a lid). The pipe is next wrapped round with hemp cloth and then steamed for one day before it is plastered over with yellow mud to a thickness of about 3 in. It is buried underground so that its upper end comes level with the ground surface. The pipe must be tightly sealed all round to prevent leakage. Firewood is then piled up on top and burnt for one day and one night until the heat has penetrated the upper section (of the pipe). Mercury will flow into the lower section without any loss".

[s] See the text as reconstructed by modern scholars, especially Mori Tateyuki (1845), p. 22; Miu Hsi-Yung[175] (+1625), ch. 3, p. 1*b*. The text is also quoted by Liu Wên-Thai[176] in his *Pên Tshao Phin Hui Ching Yao*[177] (Essentials of the Pharmacopoeia classified according to Nature and Efficacity), +1505, ch. 1, p. 1*a*; and by many other writers of pharmacopoeias.

[t] In *Thai-Phing Yü Lan*[178], ch. 988, p. 6*a*.

[u] Note the quantitative figures, not at all uncommon in mediæval Chinese texts on alchemy and chemical technology. The passage is also quoted in W/1020, ch. 68, p. 9*a*.

The same account is repeated in W/1020 (ch. 68, p. 9*a*), a Sung text[v]. A conjectural diagram of the apparatus is shown in Fig. 34.

In W/904 (pp. 2*a*, 2*b*), another Sung text, we find an illustration of a *lu* (stove) with a three-legged support and a second diagram to show how fire was conserved in the apparatus, presumably to produce a low but uniform and sustained heat. The same set of drawings reproduced in Fig. 35 also includes

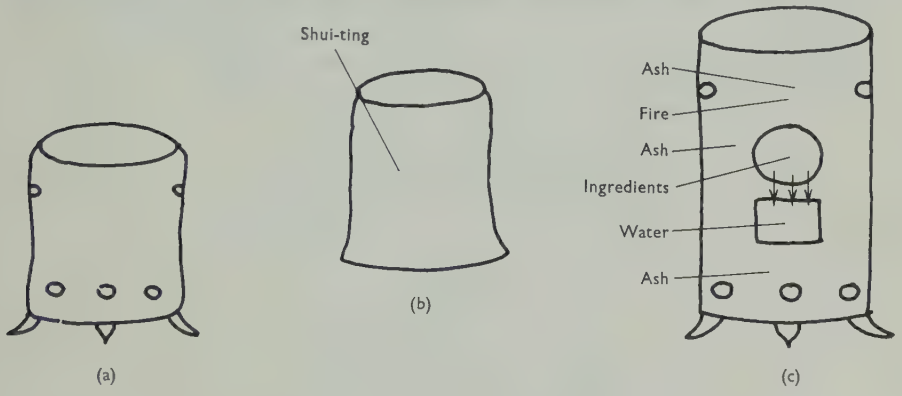


Fig. 35. Stove arranged for descensory distillation, from W/904 (Sung).

the diagram of a *shui-ting*[142], which in this case was probably a receiver partly filled with water. The text explains:

> "The *lu*[76] (stove) is made of earth or baked clay, hollow inside, and measures 2 ft. 2 in. high and 1 ft. 2 in. in diameter. There are two openings near the top and three openings near the base. The *shui-ting* (water-receiver) is made of porcelain with a capacity of about 3 pints, and the mouth fits exactly that of the reaction-vessel. Whenever the *shui-ting* (water-receiver) is used it should be filled to 6/10th or 7/10th of its capacity with boiling water. The ash inside the combustion chamber is obtained from burnt paper".

All this is clearly another method of "destillatio per descensum". Incidentally it may also give further evidence of the close-fitting surfaces or flanges which we referred to above.

In W/912 (ch. 1, p. 10*b*), a Thang text of +808, we find another illustration showing the method of *yang-huo*[108] (conserving the fire) (Fig. 36). Here the

[v] We should like to draw particular attention to this use of the ever-helpful bamboo in technology. We shall refer again shortly (p. 109 below) to the value of bamboo tubing for the Chinese alchemists and chemical technologists. As a natural pipe its availability probably led to the widespread and characteristic employment of sighting-tubes in Chinese astronomy (Needham (25), vol. 3, p. 352), and it was also responsible for the first "barrel-guns" in the shape of "fire-lances" which developed from rockets in the Sung period (see Needham (25), vol. 5, pt. 1).

reaction-chamber is surrounded on all sides, except the base, by fire, and the base is in contact with a buried water-receiver.

In W/907 (ch. 2, p. 42), the Sung text so often quoted here, we can see a further example of "destillatio per descensum" closely similar to what Agricola described and to the Dioscoridean apparatus as reconstructed by Sherwood Taylor (32). It shows a diagram of a *tzhu shih-liu kuan*[180] (pomegranate-shaped porcelain vessel) (Fig. 37). This was simply a porcelain flask (in fact an *ambix*) with a porous plug, used for converting cinnabar to mercury and its downward distillation. The flask containing cinnabar was inverted over a

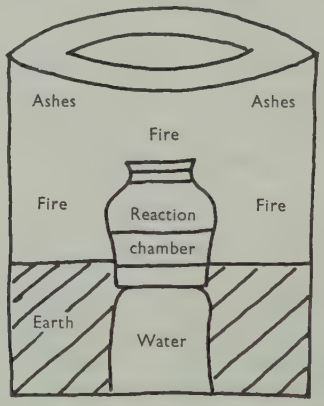


Fig. 36. Stove for descensory distillation, from W/912 (Thang).

kan-kuo-tzu[181] ("crucible"), analogous to the *lopas*, which contained some vinegar. The joint was made air-tight using a lute (equivalent to the *pelos*). Fire was then applied above. The mercury thus formed passed through the porous plug and fell into the crucible. Of course, although the apparatus was similar to that of Dioscorides, it was used for an opposite purpose, i.e. as a descensory and not a sublimatory.

To end our discussion on "destillatio per descensum" we give another example from the *Ling Wai Tai Ta*[182] (Information on What is Beyond the Passes), a text written by Chou Chhü-Fei[183] in +1178. It says[w]:

> "The people of Yung(-chou)[184] (in Kuangsi province) turn cinnabar into mercury. Iron is used to make an upper and a lower bowl-like vessel (*fu*[185]). The upper vessel holds the cinnabar which is separated (from the lower vessel) by an iron plate with small perforations. The lower vessel contains water and is buried in the ground. The two vessels

[w] Ch. 7, p. 11*a*, *b*. Note again the apposition of iron bowls, probably flanged (*cf.* p. 87 above).

are joined mouth to mouth and sealed together just at ground level. A strong fire is then applied. On being heated the cinnabar changes into vapour, and on coming into contact with water it condenses and descends in the form of (liquid) mercury".

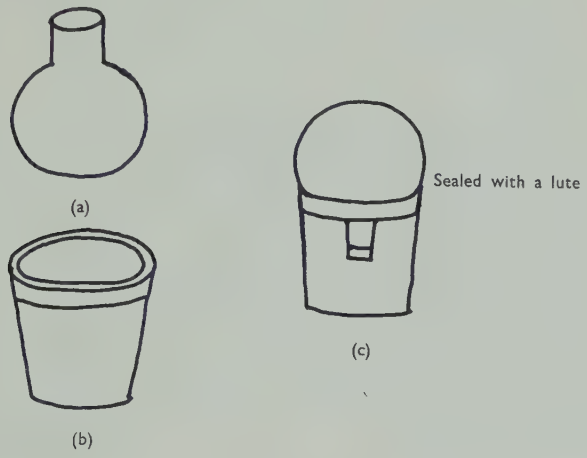


Fig. 37. "Pomegranate" vessel (ambix) used in descensory distillation, from W/907 (Sung).

(ii) East Asian Types of Still.

We must now describe the two most characteristic types of East Asian stills as found in traditional use down to the present day. The simplest form, known as the Mongol still, is seen in Fig. 38 taken from Hommel (16). The vapours from a boiling liquid in a pan (*fu*[185]) below are condensed on the under surface of a similar pan of cold water placed above, and caught in a bowl resting on a shelf in the middle of the space formed by a wooden cylindrical barrel-like wall (*thung*[186]). Such stills are used for preparing the spirit distilled from fermented mare's milk. The more developed form (Fig. 39), known throughout China and used for making vodka-like spirits from fermented glutinous rice, kao-liang, millet or other cereals, is essentially the same except that the pewter catch-bowl is provided with a side-tube (*lou-tou*[187]) forming something like an old-fashioned "churchwarden" clay tobacco pipe, and conveying away the distillate through the wooden wall into a receiver. A wooden funnel (*mu-thung*[188]) may guide the distillate into a pottery vessel standing in a small tub of cold water. This we shall refer to as the Chinese still. Both types are, of course, seated on a stove (*tsao*[68]). Fig. 40 shows a Chinese still photographed near Tung-chêng in Anhui province; the delivery tube is seen on the left and an overflow pipe from the water-cooler, assuring a constant level of cooling water,

is seen on the right[x]. Fig. 41 from Lin-chiang in Chiangsi province, shows the condenser vessel upside down, with its two handles, one of which is hollow and serves as the overflow pipe. Fig. 42 from the same place, shows the catch-bowl and side-tube upside down.

Representations of these stills in literature appear to be rare. The only Chinese-style illustration of a Chinese still which we have found is contained in

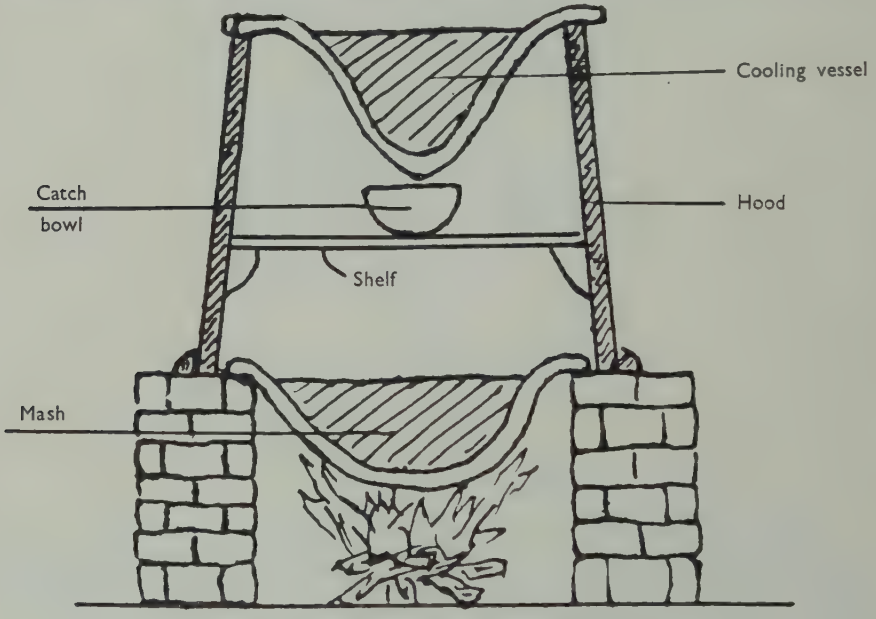


Fig. 38. The "Mongol" still (after Hommel).

the *Nung Hsüeh Tsuan Yao*[189] (Essentials of Agricultural Technology) written as late as 1900 by Fu Tsêng-Hsiang[190] but rather traditional in character (ch. 2, p. 31*b*). We reproduce this in Fig. 43. Here it is shown in connection with the making of the essential oil of peppermint. It is unfortunate that ch. 17 of the famous *Thien Kung Khai Wu*[191] (Exploitation of the Works of Nature) written by Sung Ying-Hsing[192] in +1637, which deals with wine-making, does not include a picture of a Chinese still.

Apart from the alchemical books in the *Tao Tsang*[1] we know of no other mediæval Chinese literary representations of stills. But it is to be hoped that further studies of the frescoes depicting daily life on the walls of temples and

[x] On the matter of overflow pipes to secure constant-level conditions in reservoirs, see Needham (25), vol. 3, pp. 316 ff., p. 324, for the great importance of this development in China with regard to water-clock (clepsydra) technology.

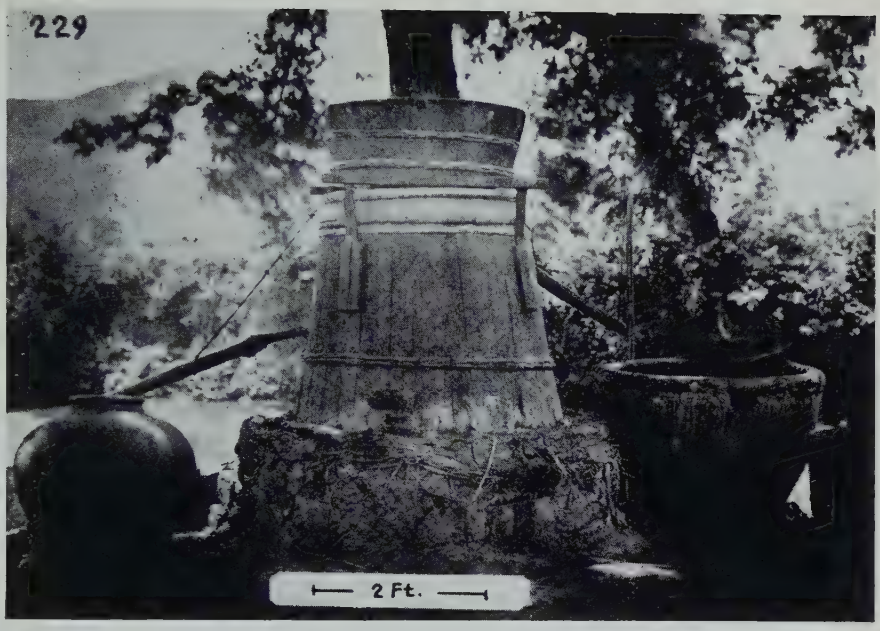


Fig. 40. Chinese still at Tung-chêng in Anhui province (Hommel, p. 142).

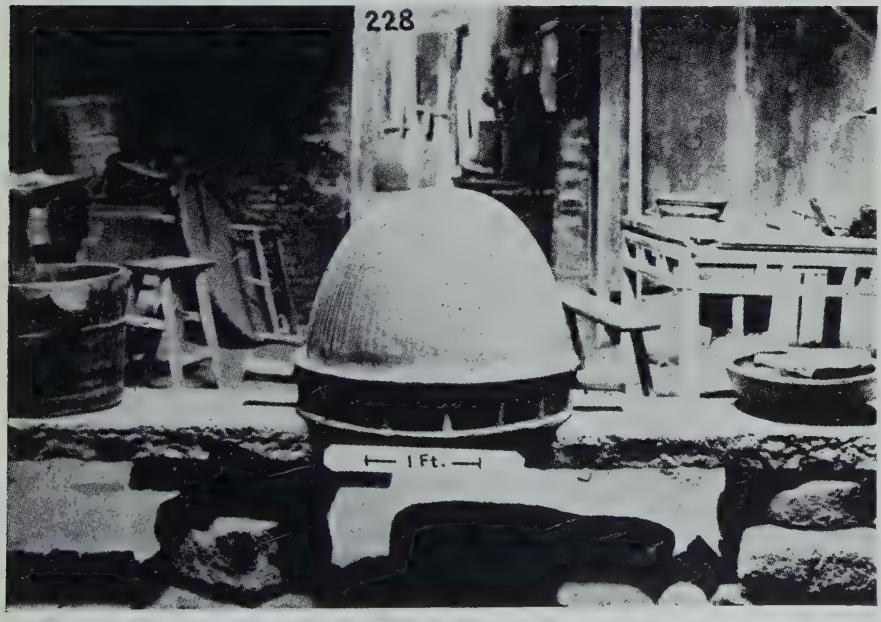


Fig. 41. Pewter condenser vessel of a Chinese still (upside down) at Lin-chiang in Chiangsi province; note the two handles, one of which is hollow and serves as the overflow pipe (Hommel, p. 144).

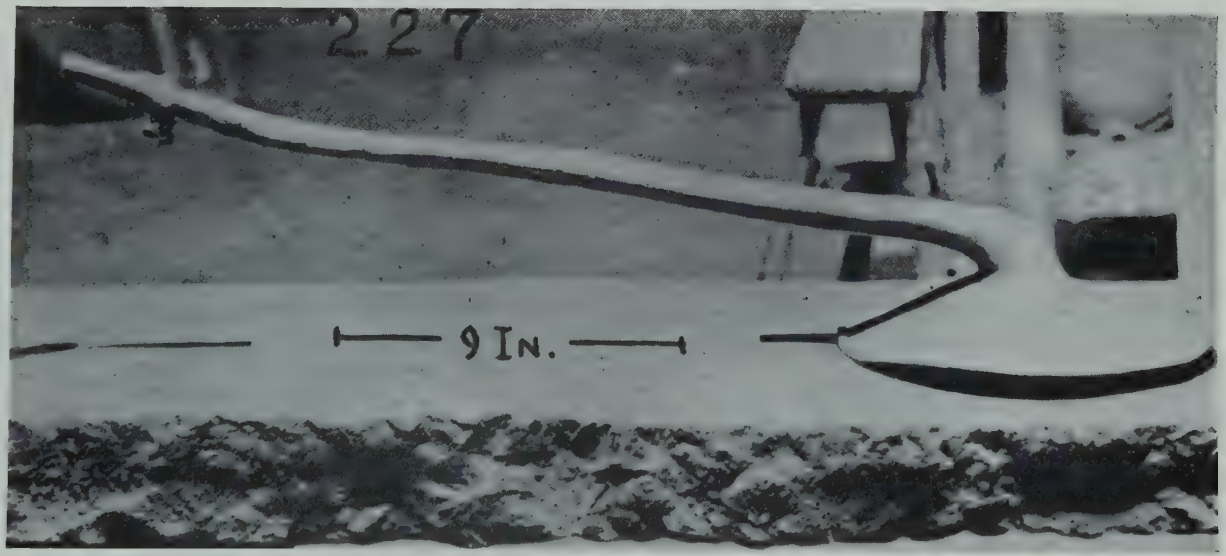


Fig. 42. Pewter catch-bowl and side-tube of a Chinese still (upside down) at Lin-chiang in Chiangsi province (Hommel, p. 144).

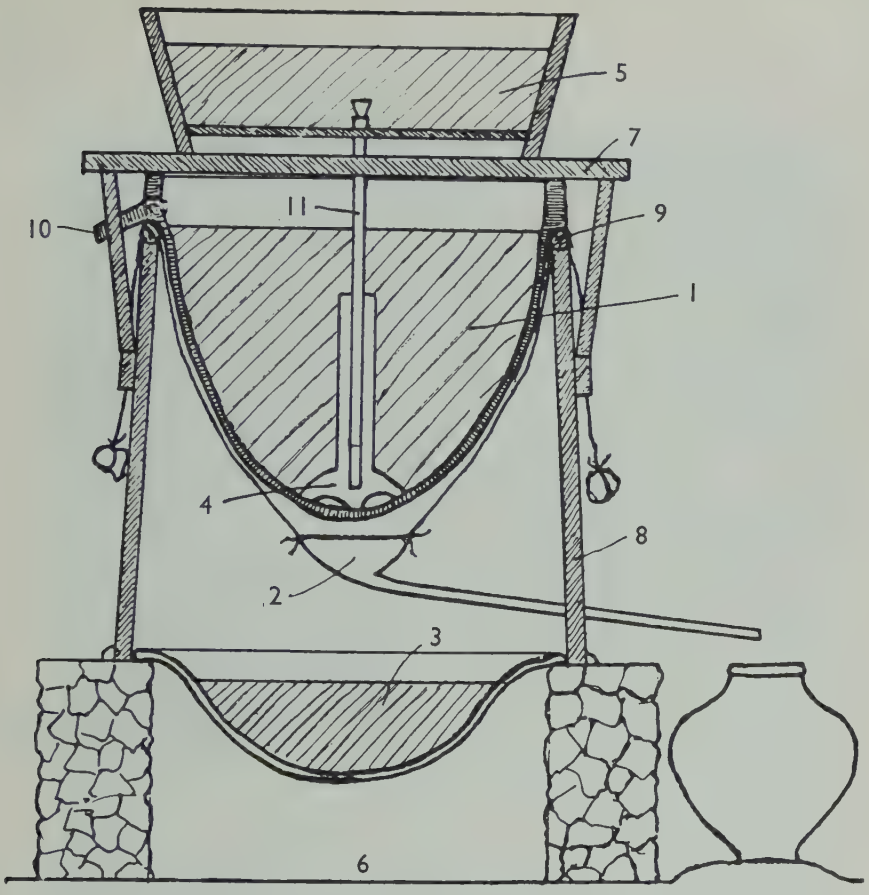


Fig. 39. The "Chinese" still (after Hommel).

1. pewter condenser.
2. pewter catch-bowl and side-tube.
3. cast-iron bowl forming bottom of still.
4. pewter funnel.
5. wooden water reservoir.
6. fire.
7. wooden frame.
8. barrel-shaped side of still.
9. gasket of sewn cloth filled with sand.
10. overflow pipe.
11. wooden pipe with wooden stopper for replenishing condenser water.

cave-temples in various parts of China may bring to light some paintings of distilling apparatus. We can here offer but one (Fig. 44), a scene of wine-making from the frescoes of the cave-temples at Wan-fo-hsia[193] (Yü-lin-khu[194]), in Kansu province[y]. This dates from the Hsi-Hsia[195] period (+1032 to +1227). We suspect that a closer study of the painting would show a side-tube leading to the cooling bucket on the right; if not, it is a painting of a Mongol rather than a Chinese still and has a catch-bowl set centrally.

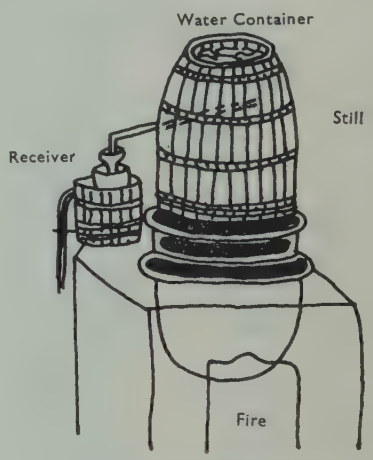


Fig. 43. Chinese still from the *Nung Hsüeh Tsuan Yao*.

Pictures of Chinese stills drawn by Europeans, or in European style, during the past two hundred years, are not uncommon. Usually one sees only the side-tube and the large bowl of cooling water at the top of the apparatus. Fig. 45 shows a late 18th-century coloured MS. drawing in the Victoria and Albert Museum[z] which was undoubtedly the original for the coloured print embodied in Mason's book (21)[aa]. The vessels at the back bear the characters *chhang li*[197] (ordinary wine for offerings). A small picture in exactly the same inconographic tradition, but cruder, will be found (in the English edition but not in either of the Chinese editions) of Li Chhiao-Phing (19), p. 199. The source is not stated.

(*iii*) *The Evolution of the Still.*

How do these facts fit in with what is known about the general history of distillation apparatus? It is curious that the two East Asian types were not taken into consideration by Berthelot (2) (p. 165) and by Sherwood Taylor (32) in their classical theory of the evolution of the still[ab]. As will be remembered, they took as their starting point the process of sublimation of mercury described by Dioscorides, where a flask-shaped vessel the *ambix*, was inverted over an iron saucer of cinnabar resting in an earthenware pot (*lopas*); cf. Fig. 46 (*b*).

[y] From the booklet of reproductions issued by the Tunhuang Research Institute in 1957, ed. Tuan Wên-Chieh[196].

[z] Print Room II-20; no. 31, D 83–1898.

[aa] Miller, London, 1800, pl. xxiv.

[ab] It is indeed the case that nothing in the least resembling the Chinese still has made its appearance in Greek, Syriac or Latin alchemical texts and diagrams, or (so far as we know) in Arabic sources. Yet see p. 96 below. Besides other references given, see Berthelot (3); Berthelot & Houdas (5), etc.

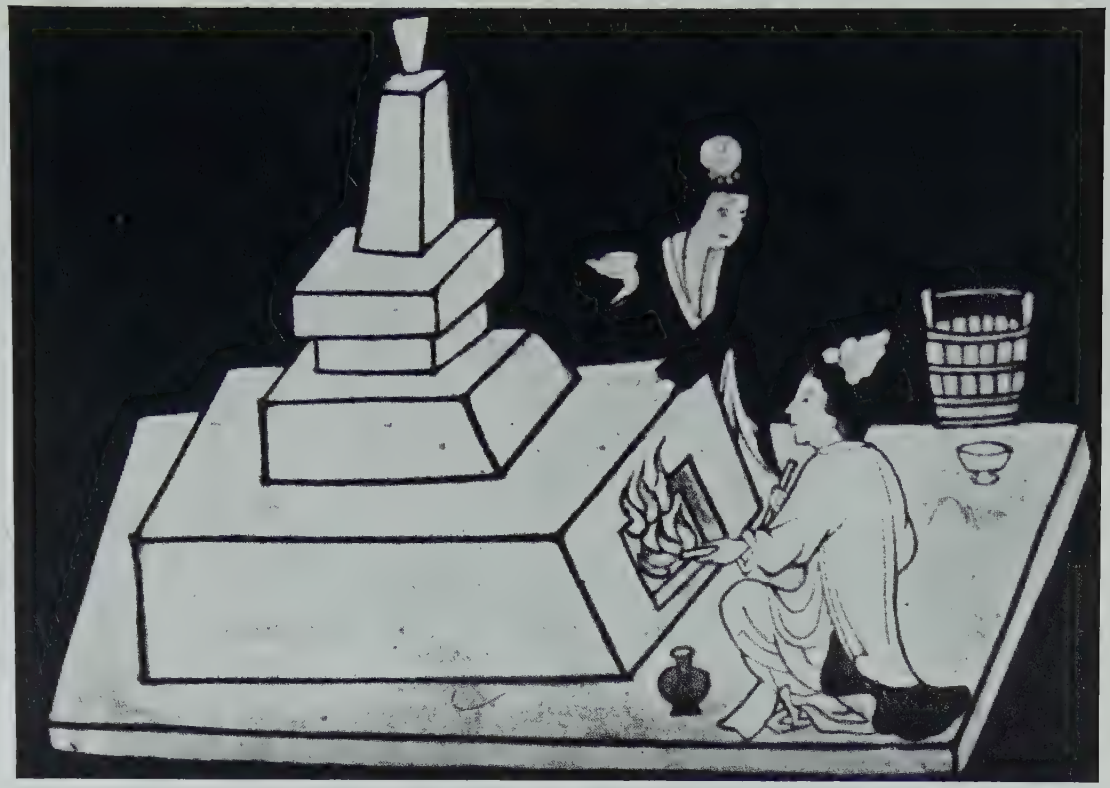


Fig. 44. A scene of wine-making from the frescoes at the cave-temples of Wan-fo-hsia (Yü-lin-khu), in Kansu province; a still. Hsi-Hsia period (+1032 to +1227), after Tuan Wên-Chieh.

Fig. 45. A late 18th-century coloured MS. drawing of a Chinese wine still.
(courtesy of Victoria and Albert Museum, London).

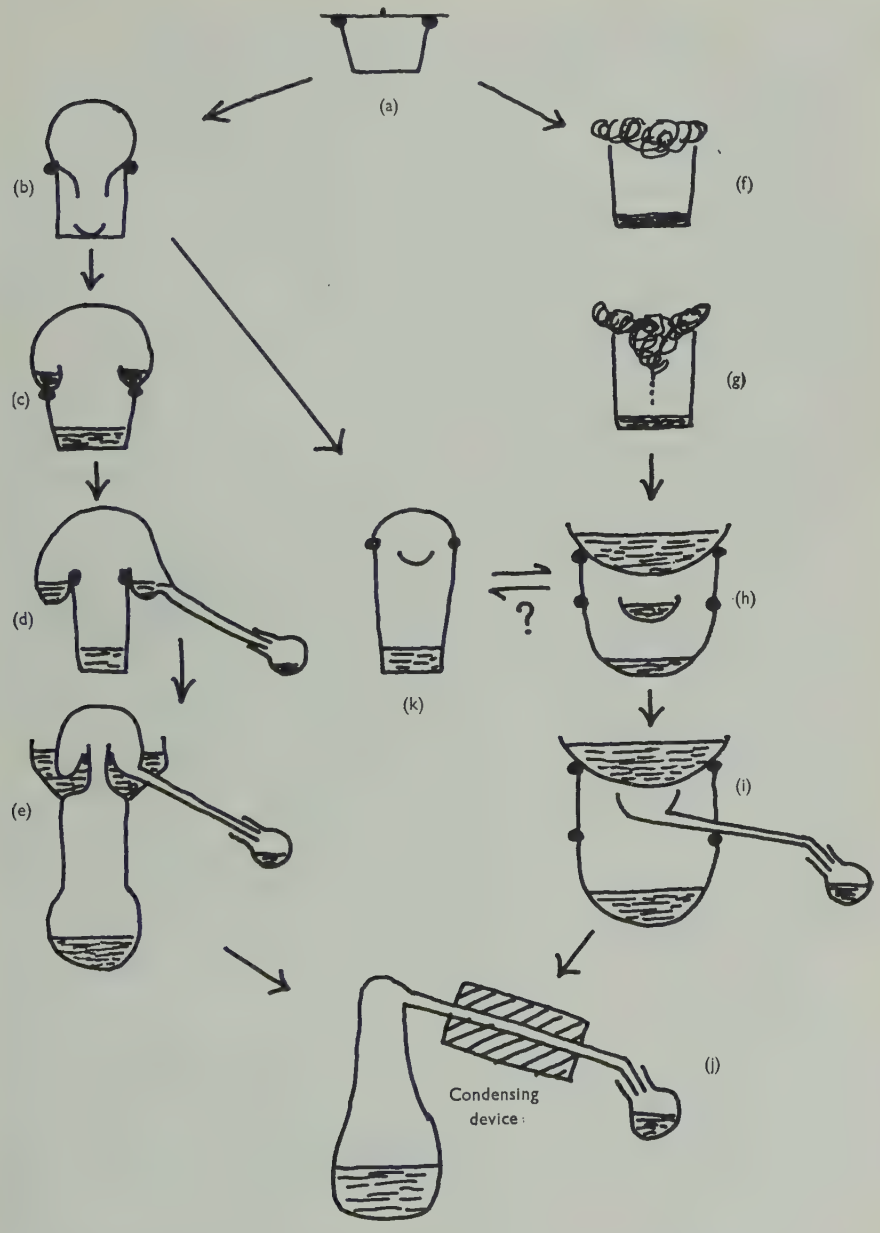


Fig. 46. Conjectural diagram to illustrate the evolution of the still; see text.

This stage itself would have derived from the simplest possible combination of heated pot and lid; cf. Fig. 46 (*a*). The next development was the better fitting together of the mouths of the two vessels, and the turning-in of the rim of the upper one so as to form an annular channel for the reception of the condensate; this might be considered the ancestor of all still-heads; Fig. 46 (*c*). Although we have shown it thus arranged, the same objective was doubtless first achieved by giving the lower vessel an annular rim into which a domical lid would direct the condensate on all sides. Mesopotamian stills of this type dating as far back as −3000 have indeed been recovered and studied by Levey (44). It may well be that the Chou bronze tripod cauldron with an annular rim (of about −500) already mentioned (p. 72 above) was an apparatus of this kind, though, like the Tepe Gawra pots, the cover has not survived. Levey also describes companion pieces having holes connecting the annular gutter with the body; these were probably used as extractors, the material to be extracted being packed in the rim. There can be no doubt that this type of apparatus is the ancestor of the "aludels with shelves" used as sublimatories by the Arabic and later Latin alchemists. Next came the addition of one or more side-tubes to convey away the distillate from the annular channel into cooler surroundings; Fig. 46 (*d*). Perhaps the art of distillation may be said to have really begun here, when it was realised that by withdrawing the condensate as quickly as possible from the heated vapour the process could be made to run continuously until completion. By the time of the first group of Greek alchemists such as Mary the Jewess, Cleopatra and pseudo-Democritus (+1st century)[ac] the technique had already developed as far as this; indeed further, for Mary (according to Zosimus) described a still-head fitted with an external water-trough acting as a condenser[ad]; Fig. 46 (*e*). Later, in the +4th century, Zosimus, Ko Hung's contemporary, added a form of still with a body of large diameter so as to give a greater evaporating surface suitable for distillation at relatively low temperature[ae]. These designs continued in use essentially unchanged until the 18th century[af].

[ac] Taylor (31); Berthelot (2), pp. 127 ff., esp. pp. 132, 136, 161, 163.

[ad] Berthelot (2), p. 138; Taylor (32), pp. 195, 196.

[ae] Taylor (32), pp. 198 ff.

[af] It is desirable to recall here that we have no illustrations of these pieces of apparatus earlier than the +11th century, the date of the most important Greek alchemical MS. (Marc. 299). Next in importance are the two Paris MSS. (2325 and 2327) of the +13th and +15th centuries respectively. It is, of course, recognised that the apparatus they depict corresponds well with the texts of the Greek alchemists themselves. By contrast in China we have printed illustrations going back to a *printed text* of the early +12th century, though none of the early editions have survived. Of alchemists contemporary with Mary and pseudo-Democritus, and even rather earlier, we have no lack in China (e.g. Li Shao-Chün[198], Liu An[199], Liu Hsiang[200], etc.) but before Wei Po-Yang[62] (+2nd century) and Ko

All this sequence of developmental stages (quite acceptable so far as it goes) presupposes that the cover which gave rise to the still-head was originally concave to the distillation space. The condensing distillate would then necessarily run down in all directions to the periphery, stimulating the invention of the annular gutter. But if the original cover had been convex to the distillation space the condensing distillate would have been seen running down to the central and lowest point before dropping back into the still body, so that there would have been a stimulus to provide first a catch-bowl, Fig. 46 (*h*) (the Mongol still); and then a catch-bowl with a side-tube, Fig. 46 (*i*) (the Chinese still). That the convex cover was traditionally a bowl of cold water we know, but what could have been the origin of such a device? Perhaps the answer was already suggested by Sherwood Taylor (32) when he referred to the technique of obtaining *pisselaion* (oil of pitch), also mentioned by Dioscorides[ag]. This consisted of stretching a clean fleece over the heated pitch and recovering the distilled oil by squeezing; Fig. 46 (*f*). An arrangement of this kind would easily have led to the convex surface we need, and it is not difficult to imagine the observation of the dropping back of distillate from the central part of such a large plug of fleece or felt; Fig. 46 (*g*). From this the characteristic East Asian still forms (*h*, *i*) could have derived. To complete this argument we are glad to be able to adduce one relevant piece of concrete evidence from that culture area, namely the use of silk floss for plugging bamboo tubes used in solubilisation ractions. This is described in the *San-shih-liu Shui Fa*[203] (Thirty-Six Methods for Bringing Solids into Aqueous Solution), a text of approximately Liang date (early +6th century)[ah].

The final stage of development (Fig. 46 *j*) when the still-head is omitted or greatly reduced in importance and the condenser devices applied wholly to the side-tube would have arisen quite naturally as the end-result of both lines of development. For once the side-tube had become a fixed part of the apparatus it would gradually be seen that the yield would be much better if the vapours were carried away as soon as formed, so that both the still-head and the catch-bowl could be dispensed with. Cooling would come about of itself if the

Hung[46] (+4th century) they did not leave alchemical writings which have come down to us. There is, however, a certain parallelism between the metallurgical material in the *Khao Kung Chi*[201] (Artificers' Record), originally −4th century and incorporated in the *Chou Li*[202] in the −2nd century; and the material on alloys in the Leiden and Stockholm papyri of the +3rd century but apparently deriving from the systematisation of Bolus of Mendes in his *Physica* and *Baphika* of the −2nd century. It would be impossible here to attempt to sketch the general history of alchemy and chemical technology in China for comparison with that of Europe, and for the present we leave entirely open all questions of priority and independence.

[ag] *Materia Medica*, I, 205.

[ah] This will be the subject of another paper by Tshao, Ho & Needham.

"side-tube" were sufficiently long. Thus we find that the still-head was dropped in certain cases very early among the Greek alchemists, for an apparatus appears in which the neck of the still is greatly elongated, and turning at a right angle is prolonged into a tube at the end of which is a receiver[ai]. Such an arrangement, however, would have favoured the deposition of distillation-products in the side-tube whence it would be difficult to remove them. Nevertheless it led directly to the type of distillation apparatus classically known in chemistry as the "retort". At what date this reached its most typical form in the West is not clear, though there is a good drawing of it in one of the Syriac MSS. studied by Berthelot & Duval (4) (p. 120). Unfortunately though these codices date from about the +10th century and contain some very old material, the MS. concerned is not older than the +16th, so that the picture in question may be as late as that time, and indeed seems drawn in quite a different style from the majority of the illustrations. We know of no Chinese drawing of the typical "retort".

The oldest European illustration of the side-tube of a still cooled by a water-jacket seems to be that of Joh. Wenod de Veteri Castro in +1420 showing the distillation of alcohol from beer[aj]. The coiled or serpentine side-tube would also seem to be a +15th-century development, as it appears in the *Liber de Arte Destillandi* of Hieronymus Brunschwyk (+1500)[ak]. The modern counter-current condenser came at the end of the +18th century, due among others to C. E. von Weigel about 1771[al].

It should not be thought that the East Asian still types play no part in modern chemical technique, and that all stills are descendants of those of the Greek alchemists. The apparatus devised by Brailsford Robertson & Ray (30) in 1924 for the continuous extraction of solids at the boiling temperature of the solvent was identical with the Mongol still except that the distillate was allowed to drip back into the still body after extracting the solid held centrally in a Buchner funnel[am]. The principle of the East Asian still, indeed, is the basis of most modern high-vacuum molecular stills. Under such conditions the fractional distillation of organic compounds in non-aqueous or nearly non-aqueous medium can be accomplished because the molecules of each substance have a characteristic mean free path. By adjusting the distance between

[ai] See Berthelot (2), pp. 140, 163; Taylor (32), p. 192.

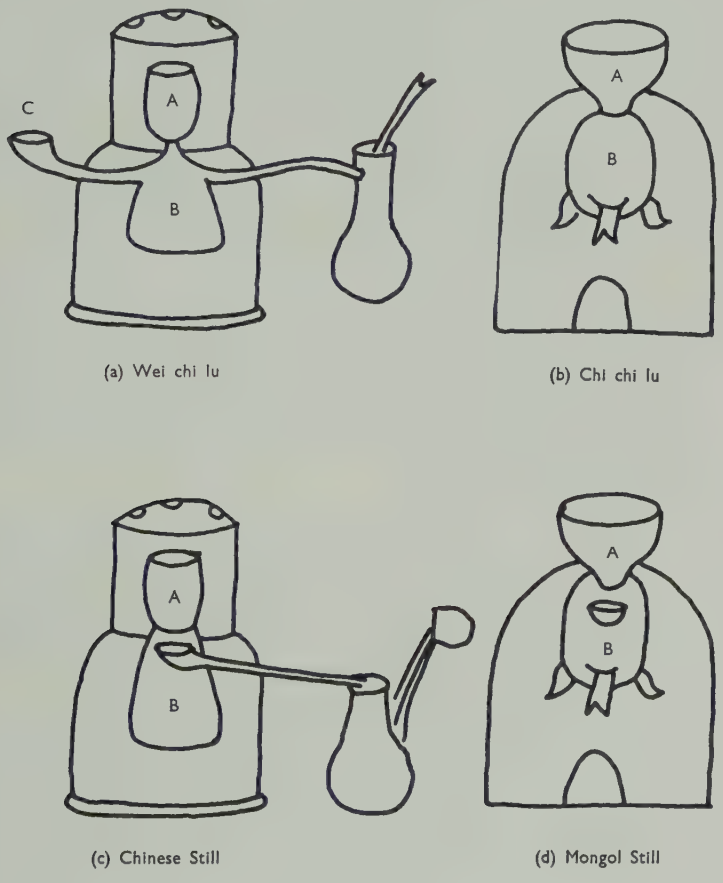
[aj] Ferchl & Süssenguth (9), p. 48; Forbes (10), p. 85.

[ak] See e.g. Ferchl & Süssenguth (9), p. 47; cf. Forbes (10), p. 84.

[al] Forbes (10), p. 255.

[am] These workers would have been surprised at the similarity of their device to that traditionally used by the Arab pharmacists in Algeria; cf. p. 107 below.

donator and receptor surfaces delicate separations may be carried out. In the Washbourn still the substance sublimes on to the convex bottom of a cooling tube; in the Hickman still a catch-bowl and pipe exactly in the Chinese style is



(a) Wei chi lu (b) Chi chi lu

(c) Chinese Still (d) Mongol Still

Fig. 47. East Asian stills, (*a*, *b*) from W/893 (Sung), (*c*, *d*) re-drawn in interpreted form.

used to remove the "disti-sublimate" condensing on an upper cooler and running down to its central point. A general description of these stills will be found in Morton (24)[an] and we noticed a good photograph of a high-vacuum still of "Chinese" type in Morrison & Morrison (23).

[an] P. 118 ff.

(*iv*) *The Stills of the Chinese Alchemists.*

We are now in a position to examine the distillation apparatus described and figured in the mediæval Chinese alchemical texts. In general we have two widely-mentioned forms of equipment the *wei-chi-lu*[204] (lit. preliminary stove) and the *chi-chi-lu*[205] (lit. accomplishing stove). Fig. 47 (*a*) and (*b*) are taken from W/893 (p. 9*a*), a text of the +12th century. Unfortunately, the text, as it has come down to us, does not describe the function of these two complicated pieces of apparatus. According to Tshao Yuan-Yü (34), Li Chhiao-Phing (19) and Huang Tzu-Chhing (17), however, in the *wei-chi-lu* the ingredients were contained in A, cold water was contained in B, and C served as an inlet for water and also as an outlet for steam. The upper section where they think fire was applied had a perforated top. Heating thus occurred around A while the space surrounding B was filled with ashes. It should be emphasized that these interpretations were those of the three modern authors named and do not arise from anything in the text itself. We shall suggest that they were confused by the relative positions of fire and water in the various forms of apparatus for "destillatio per descensum" already described. In the *chi-chi-lu* the ingredients were contained in B and cold water in A, while fire, they think (we believe rightly) was applied uuderneath B. All these forms of apparatus were sealed by using a lute or sealing-compound.

From the explanation of Tshao, Li and Huang it is difficult to see what purpose was served by the vessel shown so clearly on the right-hand side of Fig. 47 (*a*). It must surely have been the receiver of a still. Moreover, the unexplained slanting lines on the right which at first sight look like a tube are surely to be interpreted as a stream of water poured on to the receiver to cool it. One of the Indian pictures referred to below (p. 107) has exactly this. Our Chinese diagram may well have become distorted by draughtsmen who did not quite understand what they were copying. On the other hand the "inlet" C may have been drawn projecting outwards and the horizontal tube shown as continuous with the body of the still not so much for the purpose of "deceiving the experts" (as practised by the Greek alchemists), but to "discourage the layman". To quote from the preface of W/894 (a text of +806),

> "Whereupon I realised that the sages do not desire their subtle and efficacious methods to be understood by the common people who happen to come across them by chance. They have intentionally made their processes involved so that the wise would diligently pursue them, while the average person would leave them alone and indeed scorn them".

If our guess is correct then we obtain immediately the two types of East Asian still as shown in the two conjectural diagrams in Fig. 47 (*c*) and (*d*). A would then be the water-condenser vessel in both cases and B would be the body of the still. The *chi-chi-lu* would then be in effect the Mongol still, with a simple

catch-bowl at the centre, while the *wei-chi-lu* would be the more developed type or Chinese still in which the distillate is conducted away from the catch-bowl by a side-tube.

In another text (W/895, p. 1*b*) we find another diagram of a *wei-chi-lu*, reproduced in Fig. 48 (*a*). This work is ascribed to the +4th century (Chin), the time of Ko Hung and Zosimus. Again, in W/907, a text definitely of the Sung, we have two diagrams, one of a *wei-chi-lu*, Fig. 49 (*a*), and one of a *chi-chi-lu*, Fig. 49 (*b*). Now if we reconstruct both these *wei-chi-lu* drawings

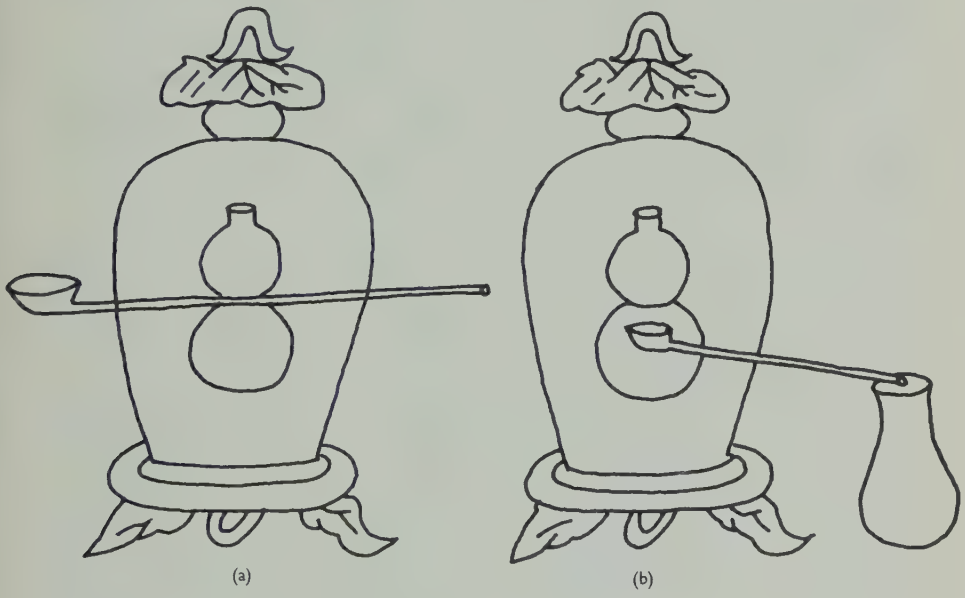


Fig. 48. The Chinese still (*a*) as in W/895 (Chin), (*b*) re-drawn as interpreted.

on the assumption that the Chinese still was what was being depicted, we get Figs. 48 (*b*) and 49 (*c*). In the former of these one might suppose that the churchwarden-pipe-like bowl and side-tube had been hung up in front of the apparatus before the artist drew it, no doubt in the elaboratory of some Taoist temple. In the latter we have to deal either with a variant in which the central collecting bowl had two side-tubes (as in our reconstruction, Fig. 49 (*c*)), or with a chance that two bowls with their side-tubes had been hung up in front of the still before the artist drew it. If the former interpretation is correct a remarkable parallel with the apparatus of the Greek alchemists presents itself, for there also one meets repeatedly with a still having two side-tubes, the *dibikos*[ao]. This occurs in fact in one of the oldest texts, the

[ao] Berthelot (2), pp. 132, 138; Taylor (31), pp. 117, 136, 137.

Chrysopoeia of Cleopatra, now consisting only of one page of diagrams. This arrangement was presumably adopted with a view to removing the distillate as quickly as possible from the hot atmosphere of the interior of the still.

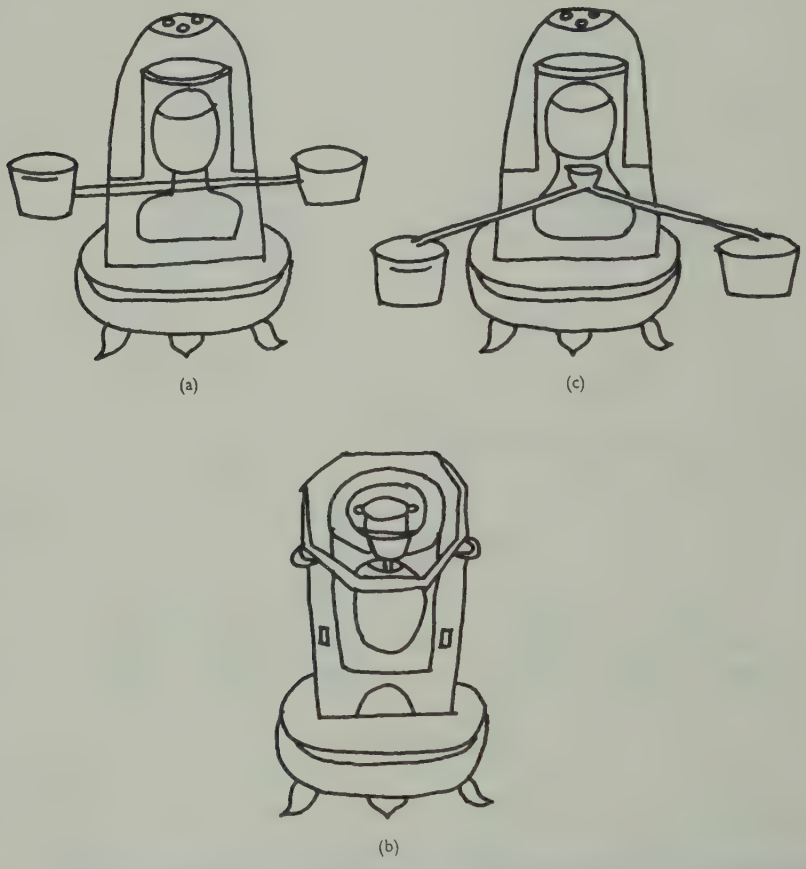


Fig. 49. East Asian stills from W/907 (Sung), (*a*) the Chinese still; (*b*) the Mongol still; (*c*) interpretation of this form of Chinese still as a *dibikos*.

Our assumption that the drawings of Figs. 47 (*a*), 48 (*a*) and 49 (*a*) represent Chinese stills not assembled for operation seems in the context quite justified. But there remains a disturbing resemblance between them and one of the Greek drawings of the *kerotakis* apparatus (Fig. 50)[ap]. As is well known, the primary form of this was a long cylindrical vessel having boiling mercury below and a palette (*kerotakis*) at the top on which was placed small pieces of copper

[ap] Marc. 299; Berthelot (2), p. 146; Taylor (31), p. 134.

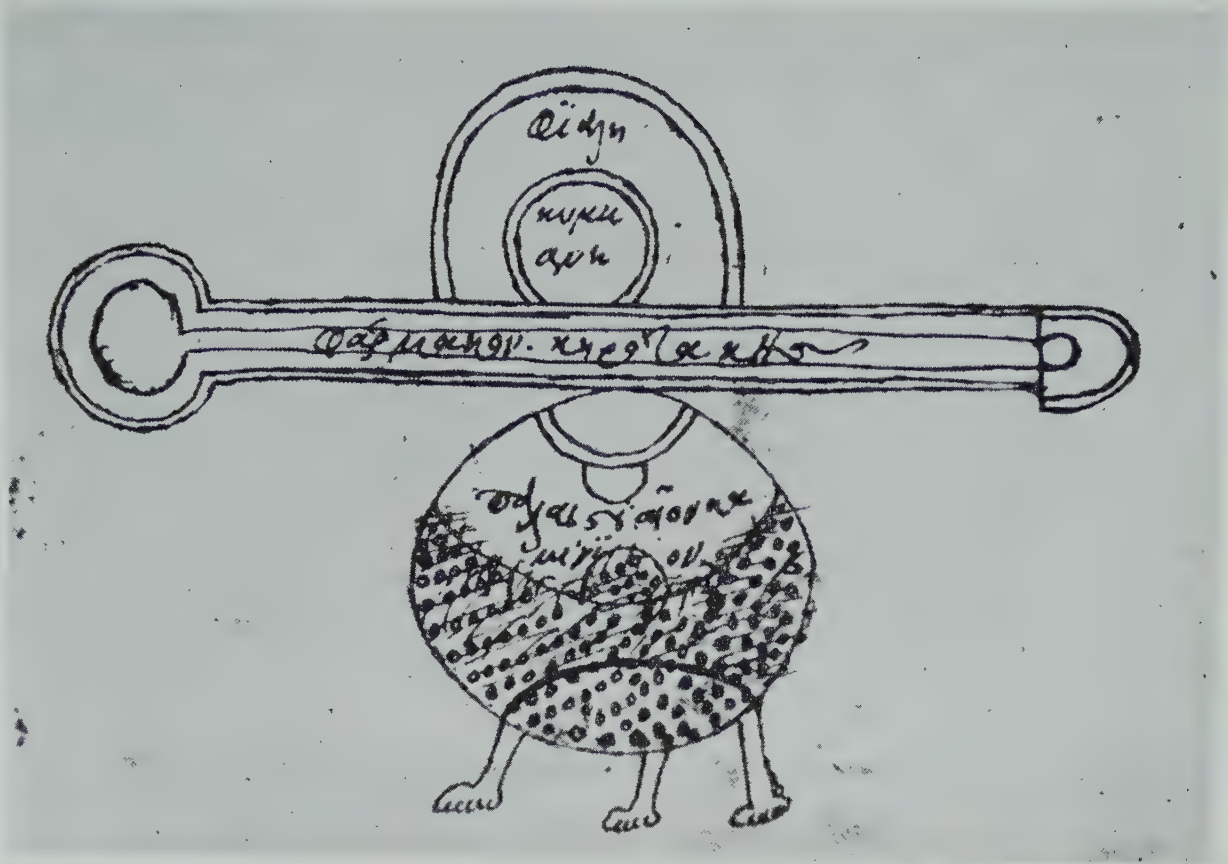


Fig. 50. One of the forms of the *kerotakis* (reflux condensation) apparatus of the Greek alchemists (Marc. 299, f. 195 *v.*) See discussion in text.

Fig. 52. Retort still for mercury (from the *Thien Kung Khai Wu* of +1637, Ming).

or copper alloys; then acting as a reflux extractor the apparatus served for the preparation of the golden-coloured alloy or amalgam of copper with 13 per cent of mercury[aq]. Globular forms of this vessel occur in various places in the MSS.,[ar] but only in one drawing does the "palette" appear as the very elongated object bisecting the two round ones which we see in Fig. 50. The legends in this drawing are also a little different from those on the others. The uppermost circle is labelled *phiale*, the standard term for a still-head, and the lowest *palaistiaion kaminion*, "little furnace a hand's-length in diameter". Below this

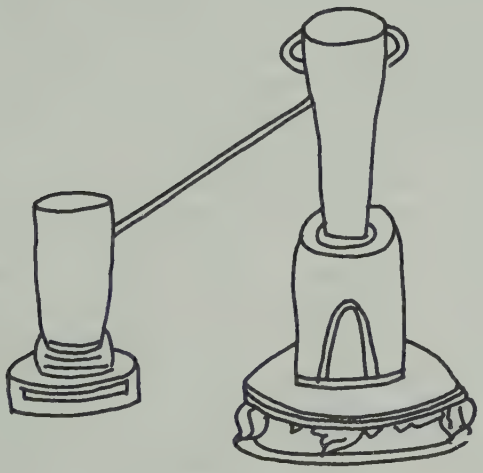


Fig. 51. Mercury still of Chinese type, perhaps with no catch-bowl at the top of the side-tube, from W/893 (Sung).

space a fire-holder in the lowest part of the vessel, pierced with holes for ash, may be assumed. Then the "palette" bears the words *pharmakon kerotakes*, "the *kerotakis* of the drug" and immediately above it the small inner circle is labelled *kumbane*, the cup. The thought arises therefore that this cup might be the same thing as the rounded left-hand end of the long horizontal component itself, in which case the whole apparatus could be considered very similar to the Chinese stills which we have been examining. That the word *kerotakis* could be very loosely used by the Greek alchemists is suggested by other places, e.g. the dialogue of Synesius (+4th century) where he directs that the still shall be

[aq] Berthelot (2), p. 143; Taylor (31), p. 132. The above interpretation was one of Sherwood Taylor's; in later writings he joined with others, e.g. E. J. Holmyard, in supposing that boiling sulphur rather than mercury was the substance at the bottom of the reflux apparatus. It is noteworthy that the analogous Indian *dhupa yantra* is distinctly stated to have sulphur and the sulphides of arsenic as the "solvent".

[ar] Berthelot (2), pp. 148, 149; Taylor (31), p. 134.

placed on a hot ash bath "which is a *kerotakis*"[as]; here the word can only mean a platform like a modern sand-bath[at]. Thus we have the possibility at any rate that the horizontal component was really a catch-bowl and side-tube (or even for part of its length a side-trough), and that the Chinese form of the still was known to the Greek alchemists. If so, it did not develop in later Greek or Latin tradition, and it would certainly be simpler to assume two quite separate lines of evolution as suggested in Fig. 46. Perhaps those who are more familiar with Greek alchemical texts than we are may be able to settle this point.

Alternatively, there is the possibility that the Chinese pictures are representations of reflux *kerotakis* extractors intended for preparing golden-coloured Cu-Hg alloys. We have little doubt that this amalgam was known to the Chinese alchemists but at the present time we are not in a position to bring forward definite affirmative evidence. The drawing of the Chinese apparatus, however, in all cases so clearly tubular, and even in one case, Fig. 48 (*a*), showing the catch-bowl so clearly, seems to us to make it much less likely that the Chinese stills were reflux extractors than that the special form of the Greek *kerotakis* was a Chinese still.

Here one perceives the strange possibility of a genetic connection between the *kerotakis* and the East Asian still. Both have a boiling liquid below (the "Hades"), and an object held in the upper central part of the vapour zone. In the *kerotakis* the purpose of the arrangement is the effecting of chemical alteration in the object's contents by the action of the vapour, with the possibility of gradual extraction of the product formed and its accumulation in the solvent at the bottom; or simply the extraction of any extractable component. The *kerotakis* is therefore the ancestor of the Soxhlet and all other modern reflux extractors. The East Asian still on the other hand uses the central object to collect the drops that fall from the uppermost ("Heavenly") condenser like rain in the meteorological water-cycle. It is thus the ancestor of the molecular still of today. But whether this logical similarity of arrangement means anything in terms of intercultural borrowing (cf. Fig. 46 *k*) it would be very hard at the present time to say. As yet there is not much to choose in priority between the first beginnings of "alchemy" or alchemical technology in China and the Hellenistic world, and mutual influences remain to be discovered. As a focal date we would only recall here the opening of the Old Silk Road in −110 and the facilitation of cultural and intellectual interchange so permitted.

We come now to types of still depicted in Chinese texts which have no catch-bowl and depend upon the withdrawal of the vapour for condensation in a

[as] Berthelot (2), p. 164; Taylor (32), p. 197.

[at] It is true that Berthelot & Ruelle (6), vol. 3, p. 65, translated differently, "such as is used for a *kerotakis*".

separate recipient. The only apparatus possibly of this kind in the *Tao Tsang*[1] occurs in W/893 (p. 7*a*), a +12th-century text (Fig. 51). The following explanation is given:

> "Ko[206], the Immortal Elder (*hsien ong*[207]) (i.e. Ko Hsüan[208], fl. +238 to +250, the great-uncle of Ko Hung) says, 'For the distillation of mercury the stove has a wooden frame (*chhuang*[209]) measuring 4 ft. (in circumference). The wooden legs reaching the stove are more than 1 ft. high so as to avoid the dampness of the ground. A hollow space is cut out (for the still to sit on). The *fu* (closed vessel) has a capacity of two pecks. Fire is kept not less than a distance of 8 in. from the vessel. The stove on the frame is made according to the size of the closed vessel'. The commentary says, 'The uppermost part of the vessel is well covered with mud (a lute) and rendered leak-proof. A tube for the vapours (*chhi-kuan*[150]) is attached to the cover as usual. Water is filled in to the water reservoir at the top. This prevents mercury from leaking'."

The quotation implies that Ko Hsüan[208] was familiar with the distillation of mercury in the +3rd century. Unfortunately, as the still-head end of the side-tube is not shown in the drawing we cannot tell whether it started in a catch-bowl under the water-container or whether it originated directly at the wall of the still.

When we come to the mercury retort in the *Thien Kung Khai Wu*[191] of +1637 (ch. 16, p. 5*b*), however, there is no longer any doubt about the separateness of the condenser. As Fig. 52 shows, no water-container is provided at the still-head, and the shape of the side-tube shows that it could not have a catch-bowl. A perfect description of this apparatus is given in a much older text from the Sung, the *Ling Wai Tai Ta*[182] of +1178. The following description strongly suggests that the retort type of still was then employed[au]:

> "The people of Kuei(-chou) (modern Kuangsi province) heat mercury to make vermilion (*yin-chu*[210]). They use an upper and a lower vessel made of iron. The lower vessel is like a bowl and holds the mercury. The upper vessel acts as the cover and has a hole through which a tube passes. The tube is bent at its upper end hangs downwards away from the vessels. The two vessels are closely and firmly fitted together. The opening of the tube is made to dip into water. The fire is applied below the lower vessel. Under the influence of the heat, the mercury distils (lit. flies up), but on coming into contact with the water (the process) is arrested . . .".

(*v*) *The Geographical Distribution of Still Types.*

A special investigation should be devoted to the history and geographical distribution of the East Asian types of still. We have already drawn upon an

[au] Ch. 7, p. 12*a*; see above, p. 103.

account of their traditional use in modern times (p. 98 above) and in what follows we shall sketch very briefly the extent of their spread.

On distillation among the Mongol peoples perhaps the best paper is that of Montell (22), who describes three types of stills (*burchur*), the Mongol one proper with the central catch-bowl, the Chinese one with a side-tube or channel originating from a bowl or a shallow grooved rectangular wooden plate, and lastly one of retort type in which the heated pot is simply connected by an arched wooden leather-covered tube with an iron receiver jug standing in a basin of cold water. Notable is the use of clay-daubed felt for making joints steam-tight, since felt was one of the most characteristic Mongol inventions[av]. All these types were and are used for obtaining spirits (*arihai*, *airiki*) or twice or thrice distilled spirit (*arsa*, *chorsa*) from fermented mare's milk (*kumys*, *airak*, *arik*) containing only some 2 per cent of alcohol.

For the Mongol still proper we need not adduce further sources but it is interesting that Pallas (27) in his famous travel book of 1776 figured two stills for making spirits from fermented milk[aw]. The Kalmuk one, lacking still-head and catch-bowl, simply had two "kettles" connected by a tube[ax], but that shown as in use among the Mongols, Buriats and Tungus was clearly provided with the upper bowl of cooling water and the side-tube with catch-bowl; it was in fact a "Chinese" still[ay]. A larger one of the same kind appears in the more recent book resulting from the travels of Maenchen-Helfen (20) in Tannu-Tuva[az]. Hermanns (14) has extended its range in his account of the Tibetan nomads whose economy is quite similar to that of the Mongols. We have not been able to find any information on other marginal zones of the Chinese culture-areas such as Korea or Indo-China.

For India the information is perplexing. Regarding the classical chemical literature, Ray (29) gives excerpts from the *Rasaratna-samucchaya*, probably of the +15th century, which apparently copied its section on apparatus largely from the +12th or +13th century *Rasendra-chudamani* of Somadeva. The descriptions and illustrations[ba] show only two regular mercury stills (the *dheki yantra* and the *tiryakpatana yantra*) with side-tubes and receivers but no cooling at the still-head, and certainly no evidence of catch-bowls. Hellenistic

[av] Cf. Olschki (26).

[aw] It is unfortunate that although the great Alexander von Humboldt personally saw distillation going on among the Kalmuks in 1829, it did not occur to him to give in his long discussion on the history of distillation (18), a precise account of the apparatus used.

[ax] Pl. III and pp. 205 ff.

[ay] Pl. VII and p. 272.

[az] Opp. p. 53; cf. also p. 57.

[ba] Revised edition, pp. 151, 158 ff., 190.

influence, as would be expected[bb], appears strikingly in the *dhupa yantra*[bc], a very precise reproduction of Mary's *kerotakis*. Nothing of East Asian style is to be seen. Moreover in a book such as Grierson's (12) description of arts and crafts in Bihar, which gives the technical terms for all the parts of the traditional liquor still[bd], the apparatus is clearly of the Western or Greek type. On the other hand, among certain primitive peoples, such as the Bhils, who distil from fermented *mahuḍa* flowers a spirit greatly used in all their ceremonies, the only still used, and the only ritually correct type of still, is the Mongol one with the catch-bowl[be]. How did this technique reach Rajputana and Malwa?

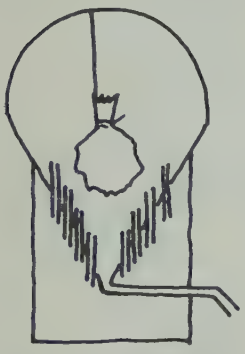


Fig. 53. Arabic extractor from Algeria, combining Eastern and Western features.

For Mogul India we have an important source in the *Ā'īn-ī Akbarī* (The Administration of the Emperor Akbar) written about +1590 by the great historian Abū'l Faẓl 'Allāmī. In his account of the imperial still-room, he describes three types of stills, the Mongol suspended catch-bowl type, the Chinese type having a "large spoon with a hollow handle leading into a jar", and the Greek still-head with two pipes and two receivers, in fact the *dibikos*[bf]. At such a late date, of course, it is difficult to trace anything of technical inter-change in earlier times.

From the close commercial contacts of Arabic and Chinese merchants all through the Middle Ages one would expect to find the East Asian still types in the Islamic culture-area. At present, however (apart from the instance just given), we cannot prove this. But we should like to call attention to the Algerian pharmaceutical still and extraction apparatus described by Hilton-Simpson (15). The still[bg] is closely similar to the water-jacketed head type of the ancient Greek alchemists already referred to (p. 96). But the extraction apparatus (Fig. 53)[bh] is a curious combination of Western and Eastern designs

[bb] From the parallel dissemination of Hellenistic mathematics and astronomy, so well known (cf. Needham (25), vol. 3, pp. 146 and 176).

[bc] Revised edition, p. 191.

[bd] Pp. 77 ff.

[be] See Pertold (28). Certain authors, e.g. Wiberg (38) continue to look upon India as the original home of all stills. We regret that we cannot evaluate his Swedish paper, which is inaccessible to us.

[bf] Blochmann (7), vol. 1, p. 69. It is rather remarkable that the only reference to the Chinese still in Forbes' (10) substantial treatise on the history of distillation should be to Abū'l Faẓl.

[bg] P. 20 and Plate III.

[bh] P. 21.

in that it has a concave roof but a central collecting point for the condensed extract surrounded by tubes permitting the rise of the vapour into the upper space.

The typical Chinese still turns up in a rather unexpected place, namely Mexico, where the characteristic apparatus for distilling *tequila* spirit from fermented *maguey* cactus juice is provided with an upper cooling water basin and a catch-bowl and side-tube underneath it. A full description is given by de la Fuente (11)[bi]. It would seem that the only route by which this could have arrived there was through the Muslim influence in Spain. Yet Wiberg (38) gives evidence that the true Mongol still is found among the Huichol Indians in Mexico.

Conversely, stills of Western or Greek type, especially for preparing essential oils, are found in China. Or so we must assume from the illustration of a cassia oil still with annular rim, no cooling basin at the head, and three successive baths round the side-tube, shown in Li Chhiao-Phing (19)[bj]. Guppy's description (13) of *samshu* (*san shao*[211]) distillation in North China in the eighties of the last century points to the same thing as he speaks of a gutter. "The fermented millet" he wrote, "is placed in a large wooden vat or tub, the bottom of which is made of a kind of grating, and beneath the vat there is a large boiler of water heated by an adjacent furnace. The steam ascending through the grating and passing through the fermented millet finally comes in contact with a cylinder of cold water; it is there condensed and trickling off into a little gutter, finds its way out through a long spout in a clear stream of veritable *samshu*". These words are interesting not only on account of the implied peripheral channel, but also because they link the apparatus with the ancient "steamers" of the Chou and Han.

It is thus evident that much further research will be needed before we can hope to translate the theoretical diagram of the evolution of the still in Fig. 46 into terms of the concrete appearance and development of the different forms among the various peoples in successive ages. But the task would be a fascinating one.

(8) *Accessories*

Numerous accessories are mentioned in W/874, a Liang text. For pounding and grinding the Chinese alchemists used different types of pestle made from jade (*yü-chhui*[212]) or stone (*shih-chhui*[213]). W/886 mentions the use of a pestle made from willow wood (*liu-mu-chhui*[214]), while W/885 describes the use of an antelope horn (*ling-yang-chio*[215]) for grinding. Fig. 54 taken from W/893 (p. 11*b*) shows a mortar used by the alchemists of the Sung.

[bi] See his fig. 11, p. 97.

[bj] His fig. 73 opp. p. 148; again this is in the English edition only, and again without statement of origin. But it occurs in a different form in Forbes (10), p. 7, where it is credited to the Indian Institute, Amsterdam.

After the process of grinding or pounding the fine particles were separated from the coarser ones by means of various types of sieve. One made of horse-hair, called the *ma-wei-lo*[216] and another of fine silk, called the *chhing-sha-lo*[217] are mentioned in W/874, written in the Liang period.

For transferring or removing ingredients the same text describes the use of an iron spoon (*thieh-shih*[218]) and iron chopsticks (*thieh-chu*[219]). In Chinese museums one may see bronze ladles with a handle as well as three legs (e.g. at Chung-king). For collecting the substance which adhered to the surface of the vessel a feather, usually from a cock, was used as a scraper. W/885 informs us of a silver spoon (*yin-pi-tzu*[220]).

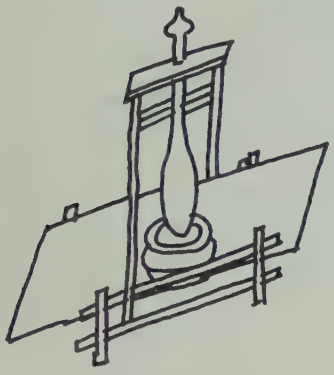


Fig. 54. Pestle and mortar, from W/893 (Sung).

Very often the alchemists had to render their reaction vessels air-tight. Several forms of luting material were used. They ranged from ordinary beeswax to the well-known "six-and-one mud" (*liu-i-ni*[221]), a lute made of seven different substances. We intend to discuss this elsewhere.

For reactions in solution a bamboo tube was sometimes used. The *chuthung*[221] (bamboo pipe) consisted of a section of bamboo, with walls thinned by shaving and immersed in a liquid such as vinegar This is widely used in the *San-shih-liu Shui Fa*[203] W/923; (Thirty-Six Methods for Bringing Solids into Aqueous Solution) a book probably of the Liang period. This also will be the subject of another paper. W/874, another Liang text, describes the use of a bag made of cloth (*pu-tai*[222]) for the same purpose.

Taoist texts, for example W/885, make frequent reference to weighing, but no special description of the balance or weighing-machine has yet been found. It is probable that the alchemists used the ordinary steel-yard, which was always the most common type of balance in China. It is also interesting to note the use of the clepsydra (water-clock) and the sundial for timing the initiation and duration of alchemical experiments, as mentioned, e.g. in the Sung text W/229.

A good deal of alchemical apparatus seems to have been ordinary household and kitchen utensils pressed into service. The use of iron chopsticks, iron and silver spoons, stone pestles, etc., has already been mentioned. Other things like large jars, wooden basins, vases and copper basins, for example are mentioned in W/935, a text of ca. +864. W/874 also tells us about such ordinary household utensils as the *chhêng*[223], a vessel with feet usually used for warming wine; the *thieh-chhi*[224], a container made of iron, and the *kuo*[225], presumably the

large thin-walled cast-iron pan for frying or boiling food normally found in Chinese kitchens.

It must doubtless seem unsatisfactory to consider Chinese alchemical apparatus, especially stills, in the rather abstract way to which we have been constrained here by our immediate purpose. We have no doubt that Chinese literature from the Han onwards contains a large number of textual references which will throw light on the progress of chemical technique in that great civilisation. Some of them we already know[bk]. But this must be left for another paper. Here we can only record our belief that development went on *pari passu* with that of European alchemy, and that Ko Hung probably knew quite as much about chemical operations as Zosimus. At any rate we hope that enough has been said about the Chinese equipment to dispel the impression given by some older authorities, who without any access to original texts, could write, e.g., "They (the Chinese) possessed neither characteristic chemical methods of their own, nor any apparatus originating in their own culture"[bl].

[bk] Cf. a +13th-century passage which sounds very like a gold-mercury amalgamation in a *kerotakis*, quoted in Needham (25), vol. 2, p. 333.

[bl] Von Lippmann (43), vol. 1, p. 456, cf. p. 459.

Acknowledgment

The authors are much indebted to Professor J. R. Partington for the benefit of his counsel and critical discussions.

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CHRONOLOGY OF CHINA.

Hsia kingdom (legendary?)		ca. −2000/ca. −1500	
Shang (Yin) kingdom		ca. −1500/ca. −1030	
Chou dyn. (Feudal Age)	Early Chou period	ca. −1030/−722	
	Chhun Chhiu period	−722/−480	
	Warring States period	−480/−221	
First Unification	Chhin dyn.	−221/−207	
	Han dyn. Earlier or Western Han	−202/+9	
	Hsin interregnum	+9/+23	
	Later or Eastern Han	+25/+220	
First Partition	Three Kingdoms Period (San Kuo)	+221/+265	
	Shu (west)		+221/+264
	Wei (north)		+220/+265
	Wu (south-east)		+222/+280
Second Unification	Chin dyn.: Western	+265/+317	
	Eastern	+317/+420	
	Former (or Liu) Sung dyn.	+420/+479	
	[Northern Wei dyn. (Tho-Pa Tartar) later split into Eastern and Western		+386/+554]
Second Partition	Northern and Southern Empires (Nan Pei Chhao)	+479/+581	
	Chhi (southern)		+479/+502
	Liang		+502/+557
	Chhen		+557/+587
	Chhi (Northern)		+550/+577
	Chou (Northern)		+557/+581
Third Unification	Sui dyn.	+581/+618	
	Thang dyn.	+618/+906	
Third Partition	Five Dynasty period (Wu Tai)	+907/+960	
	Later Liang		+907/+923
	Later Thang		+923/+936
	Later Chin		+936/+946
	Later Han		+947/+950
	Later Chou		+951/+960
	[Liao dyn. (Chhi-Tan Mongol)	+907/+1125]	
	[Hsi Hsia State		+990/+1227]
Fourth Unification	Northern Sung dyn.	+960/+1126	
Fourth Partition	Southern Sung dyn.	+1127/+1279	
	Chin (Ju-Chen Tartar) dyn.	+1115/+1234	
Fifth Unification	Yuan (Mongol) dyn.	+1260/+1368	
	Ming dyn.	+1368/+1644	
	Chhing (Manchu) dyn.	+1644/+1911	
	Republic	+1912 on	

道藏
陳國符
開元
玄宗
安祿山
史思明
咸通
黃巢
真宗
王欽若
張君房
大宋天宮寶藏
徽宗
政和
萬壽道藏
世宗
大金玄都寶藏
天長觀
宋德方
玄都寶藏
憲宗
世祖
正統道藏
萬曆續道藏
白雲觀
曹元宇
李喬苹
黃子卿

29. 袁翰青
30. 還丹秘訣養赤子神方
31. 許明道
32. 太清石壁記
33. 楚澤
34. 翁獨健
35. 黃帝九鼎神丹經訣
36. 大洞鍊真寶經九還金丹妙訣
37. 陳少微
38. 太上衛靈神化九轉還丹砂法
39. 九轉靈砂大丹
40. 玉洞大神丹砂真要訣
41. 丹房須知
42. 吳悞
43. 石藥爾雅
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45. 雅川真人校證術
46. 葛洪
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48. 修鍊大丹要旨
49. 金華冲碧丹經祕旨
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51. 還丹肘後訣
52. 諸家神品丹法
53. 孟要甫
54. 玄真子
55. 鉛汞甲庚至寶集成
56. 趙耐菴
57. 通玄祕術
58. 沈知言
59. 太極真人雜丹藥方
60. 庚道集
61. 周易參同契
62. 魏伯陽
63. 雲笈七籤
64. 張君房
65. 上陽子金丹大要圖
66. 陳致虛
67. 壇
68. 罐
69. 藥鑪
70. 鼎
71. 砂合
72. 神室
73. 混沌
74. 龍虎丹臺

75. 參同錄
76. 爐
77. 蓬壺
78. 五岳
79. 北斗
80. 華池爐
81. 太一鑪
82. 支
83. 丹鑪
84. 墊
85. 偃月鑪
86. 鍋釜
87. 張隨
88. 威光鼎
89. 生鐵
90. 藥釜
91. 陽爐
92. 武火
93. 禹縣
94. 匱
95. 考古通訊
96. 金鼎
97. 銀鼎
98. 銅鼎
99. 鐵鼎
100. 土鼎
101. 升
102. 懸胎鼎
103. 三才
104. 朱砂鼎
105. 太一神鑪
106. 混沌鼎
107. 威光鑪
108. 養火
109. 黃芽匱
110. 白虎匱
111. 黑虎匱
112. 黃匱
113. 懸針匱
114. 立制匱
115. 糝制匱
116. 湧泉匱
117. 天生黃芽匱
118. 砒匱
119. 紫河車
120. 砒末
121. 河車
122. 甘堝
123. 養
124. 粉霜
125. 青鹽
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130. 鐵釜
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139. 鬳
140. 周禮
141. 火鼎
142. 水鼎
143. 火盆
144. 子
145. 午
146. 卯
147. 酉
148. 丹鼎
149. 混沌胎元
150. 氣管
151. 丹胚
152. 赤石脂
153. 金土
154. 白金
155. 水海
156. 赤泥
157. 外鼎
158. 混沌雛子

159. 水管子
160. 混沌合
161. 礬石
162. 銀珠
163. 三水筧
164. 汞鼎
165. 銀蓋
166. 釭鐙
167. 釭
168. 鐙
169. 閻翁主銅釭鐙一具
170. 西清古鑑
171. 梁詩正
172. 金定
173. 神農本草經
174. 淮南萬畢術
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176. 劉文泰
177. 本草品彙精要
178. 太平御覽
179. 光明砂
180. 磁石榴罐
181. 甘堝子
182. 嶺外代答
183. 周去非
184. 邕州
185. 釜
186. 桶
187. 漏斗
188. 木筒
189. 農學纂要
190. 傅增湘
191. 天工開物
192. 宋應星
193. 萬佛峽
194. 榆林窟
195. 西夏
196. 段文杰
197. 常豐
198. 李少君
199. 劉安
200. 劉向
201. 考工記
202. 周禮
203. 三十六水法
204. 未濟爐
205. 既濟爐
206. 葛
207. 仙翁
208. 葛玄
209. 床
210. 銀朱
211. 三燒
212. 玉槌
213. 石槌
214. 柳木槌
215. 羚羊角
216. 馬尾羅
217. 輕紗羅
218. 鐵匙
219. 鐵箸
220. 銀匕子
221. 竹筒
222. 布袋
223. 鑷當
224. 鐵器
225. 鍋
226. 白銅
227. 廣雅
228. 張揖

REVIEWS

Robert Boyle and Seventeenth-Century Chemistry. By Marie Boas. Pp. 240. Cambridge University Press, 1958. Price 30s.

When one considers the large amount of attention that has been devoted in recent years to the appraisement of Lavoisier's epoch-making achievements, and the comparative paucity of attention directed to the work of Boyle and other chemists of the 17th century, who, as the present author stresses, "provided much of the background which made Lavoisier's synthetic feat possible", this book is a particularly welcome contribution to the subject in question; for it is based not only on an extensive survey of the period literature, but on the first thorough study of Boyle's manuscripts, which Henry Miles (1698–1763) had bequeathed to the Royal Society.

Dr. Marie Boas contends that historians have always presented a distorted portrayal of 17th-century theoretical chemistry and, in her opinion, this distortion results in a very large part from the brilliant success of Lavoisier in creating a revolution in this science. Indeed, as Ernst von Meyer had emphasised more than fifty years ago: "Nothing is less justifiable than to assert that chemistry was at that time no science, and that it was Lavoisier who created one out of what was, before his time, a science only in name. The record of Boyle . . . and others is sufficient to prove the error of such an assumption". But hitherto there has never been any scholarly attempt to assess Boyle's place in the history of chemistry; and Dr. Boas (who is Assistant Professor of the History of Science in the University of California) has, by using the work of Boyle as "a point of departure", clearly delineated both those aspects in which he was original and those aspects in which he was but typical of his times—thus fulfilling her objective to reveal "what the chemistry which was a part of the scientific revolution was trying to do, and what it did do to prepare the way for the more spectacularly successful revolution in chemistry which took place in the 18th century". Moreover, as a critical historian, Dr. Boas has not succumbed to the customary description of alluding to Boyle as the 'Father of Modern Chemistry', for, as she rightly says: "No man was that—besides it is by no means clear how much of Boyle's work was original, and how much was based upon others"; his influence on the development of chemistry was, in fact, profound, even though he is better known through his achievements in physics. Furthermore, it is also pointed out that if modern historians find it hard to see why Boyle's influence on chemistry was so enormous, this is partly because of the complex development of chemistry during his lifetime, and partly because his contributions to the new chemistry permit no such easy categorisations as do his contributions to the new physics. It was, of course, through the introduction of a physico-chemical philosophy crystallised, so to speak, in his *Sceptical Chymist*, that Boyle undermined both the peripatetic hypothesis of the four elements and the Spagyrical doctrine of the *tria prima*.

In chapter III of the book under review, we are given a lucid account of the various theories of matter that were current when Boyle began to develop his own corpuscular theory—a theory which enabled him logically to consider transmutation as a perfectly feasible chemical operation; this outlook does

not mean that he was "slipping into mystical alchemism" but, as the author goes on to remark: "he had, he thought, found a way of explaining yet one more occult operation in mechanical terms . . . [i.e.] in terms of concrete, tangible chemical entities, rather than in the old occult terms of abstract *a priori* undetectable principles".

Dr. Boas has divided her main subject matter into seven chapters under the headings: "The Making of a Scientist"; "The New Chemistry"; "Chemical and Physical Theories of Matter"; "The Problem of Chemical Composition"; "Chemical Composition and Chemical Theory"; "A Digression on Air"; and "Scientific Method and Chemical Technique". There is a bibliography and a sufficiently comprehensive index. In the bibliography, however, there are a few errors and misprints which have escaped correction in the proof reading; for instance, the entry "Paracelsus. In A. E. Waite, ed., *Hermetic Museum*, London, 1894" should presumably read: "Paracelsus. In A. E. Waite, ed., *The Hermetic and Alchemical Writings of Paracelsus*, London, 1894". But these are minor points that do not detract from the author's scholarly and stimulating treatment of this important study of Robert Boyle and 17th-century chemistry. D. G.

A History of Western Technology. By Friedrich Klemm. Translated by Dorothea Waley Singer. Pp. 401. 59 Figs., 24 Plates. London, Allen & Unwin. 1959. Price 32s.

This book is the first English translation of Dr. Klemm's *Technik: Eine Geschichte Ihrer Probleme*. In the translator's prefatory note, it is stated that "the author's main object is to contribute towards a wide popular understanding of technological history".

Dr. Friedrich Klemm (who is librarian of the Deutsches Museum, Munich) has not, in fact, written a history, as indicated by the chosen title of this book, but he has given us a compilation drawn from a wide circle of sources that quote from documents relating to technology, beginning with Graeco-Roman times and concluding with a mention of modern computing machines. Interpolated with much of this *corpus* of extracted material there is what one might describe as a kind of running commentary, and this, whenever considered applicable, is frequently illustrative of Puritan and Calvinistic literature. For example, and to mention only one instance, there are long citations from Richard Baxter's *A Christian Directory* (2nd ed., London, 1678). These multitudinous extracts of pious sentiments are, in the present reviewer's opinion, somewhat difficult to be aesthetically absorbed in the framework of a source-book of technology, and their inclusion does not aid in assimilating the main text of the book. But full use has been made in the reproduction of a lavish selection of illustrations taken from the literature of various periods, and these illustrations provide an added interest to the text. Moreover the vast amount of valuable information contained in this book, makes it a useful and interesting compendium of technological history for the general reader.

The book concludes with a list of references to the sources quoted in the text, a select bibliography, an index of names, and a general index. D. G.

PUBLICATIONS RECEIVED

Archives Internationales d'Histoire des Sciences. No. 43, April-June, 1958. Paris, 12 rue Colbert. Price 2500 francs.

This issue contains an article by Marie Boas & A. Rupert Hall on "Newton's Chemical Experiments". The authors discuss some of the contents of two important documents written by Newton, which are preserved in the Cambridge University Library. One of these documents is a notebook (now pressmarked MS.Add.3975); and very similar experiments, sometimes identical with those of the notebook, are recorded on loose folded sheets (MS.Add.3973). From a detailed and critical study of these 'chemical' notes, it is inferred that although the use of alchemical terms in the notes "gives an air of esoteric mystery to Newton's chemical pursuits which seems, in fact, not to be wholly warranted", his use of alchemical terminology cannot be construed as implying that he was an alchemist, "but it seems eminently reasonable to suppose that even in his most esoteric alchemical language, he intended to speak chemical sense". Moreover, the majority of his recorded experiments are shown here to deal with (*a*) the volatilization and fusibility of metallic alloys, (*b*) the composition of a number of chemical compounds; and it is clear that "he was as good an experimental chemist as he was an experimental physicist".

The article cites copious extracts from these notebooks, and it is pointed out that Newton's chemical notes are far from easy to understand; for he used "non-standard" symbols in addition to those generally ascribed to the metals and other materials. The authors give us their conjectured interpretations of these less usual symbols and terms, together with textual reproductions of the originals in question; they also state that there are other non-standard symbols, and various names of substances occurring in the notes, to which it has not yet proved possible to attach a definite significance. They conclude that Newton did seek to correlate alchemical language with experimental facts, but his experiments read like those of a rational experimental scientist at a time when alchemy could not be discounted; and that he was not in any admissible sense of the word an alchemist—for there is no evidence in Newton's chemical notes "that any of his processes are of the kind necessarily preliminary to the Great Work, or that he ever hoped to fabricate a factitious gold".

It is alleged in this article that Sherwood Taylor claimed that the Newtonian document *Sententiae Notabiles* (King's Coll. MS. 38) was "Newton's own"; but the present authors have apparently overlooked that, in fact, Sherwood Taylor clearly stated: "It is true that very little of that text was originated by Newton, but it is equally true that he produced it by selecting as noteworthy particular passages out of treatises amounting to hundreds of thousands of words . . . " (cf. *Ambix*, V, 1956, p. 64).

Newton's extraction of alchemical books is, the authors affirm, difficult to explain save as the result of a "psychological compulsion"; and the opinion is expressed that "probably we shall never know what directed Newton to alchemical writings, and what was the development of his attitude towards their content".

The question arises: "What kind of chemical philosopher was Newton?" There is, we are told, no direct answer to this question that can be derived from the notebooks: "The historian seeking to answer it must still look elsewhere".

Chymia. Annual Studies in the History of Chemistry. Edited by Henry M. Leicester. Volume 5. Pennsylvania, University Press: London, Oxford University Press, 1959. Price 40s.

THIS volume opens with a biographical and bibliographical memoir by H. S. Klickstein on Edgar Fahs Smith, whose large collection pertaining to the history of chemistry was, on the death of Dr. Smith in 1928, presented by his widow to the University of Pennsylvania for the establishment of the present Edgar Fahs Smith Memorial Collection in the History of Chemistry.

The first article is by Martin Levey on "The Refining of Gold in Ancient Mesopotamia", and this paper is primarily concerned with the new evidence from cuneiform tablet sources on the subject of its title. The same author, in collaboration with J. E. Burke, also contributes "A Study of Ancient Mesopotamian Bronze". Trevor Robinson writes on "Theophrastos On Fire" and gives an edited translation of the essay "On Fire". Under the heading "Chemistry in Kautilya", Priyadaranjan Rây gives a concise account of varieties of information on chemical and other scientific knowledge to be found in the very ancient Indian work *Arthaśástra* of Kautilya. It is considered that the extant *Arthaśástra* is possibly a later recension of the earlier work of Kautilya, and was prepared some time after 300 B.C., but before A.D. 300; it is concluded that alchemy received little favour or credence in India in Kautilya's time; and that it is certainly of much later growth in India, possibly taking its root on the decline of Buddhism by the 7th or 8th century A.D. The next article is on "Some French Antecedents of the Chemical Revolution" by Henry Guerlac; and this precedes a paper by Maurice Daumas & Denis Duveen on "Lavoisier's Relatively Unknown Large-Scale Decomposition and Synthesis of Water, February 27 and 28, 1785": Meusnier's notes and reports of Lavoisier's experiments are reviewed from the original documents acquired a few years ago by Mr. Duveen, and now preserved in the Duveen Historical Library. J. R. Partington writes on "Berthollet and the Antiphlogistic Theory": it is considered that Berthollet had abandoned the phlogiston theory and adopted the antiphlogistic theory on 6 April, 1785, whereas Duveen & Klickstein had (in 1956) concluded that the approximate date was between August, 1786, and April 1787. Henry M. Leicester contributes a paper on "The Spread of the Theory of Lavoisier in Russia"; Wyndham D. Miles discourses on "The Columbian Chemical Society"; and Sidney M. Edelstein writes on "The Chemical Revolution in America, from the pages of the 'Medical Repository' ". The three final articles are on: "Josiah Wedgwood, Industrial Chemist", by Robert E. Schofield; "The Chemical Philosophy of Humphry Davy", by Robert Siegfried; and "History of the Structure of Acetone", by Mel Gorman & Charles Doering.

A name index concludes this interesting volume of *Chymia*.

Revue d'Histoire des Sciences et de leurs Applications. Tome XI, No. 4, (October-December), 1958. Paris: Presses Universitaires de France. (Annual Subscription to Great Britain and the Commonwealth, 24s.)

THIS issue contains the following articles:—

André Robinet: "L'abbé de Catelan, ou l'erreur au service de la vérité".

Arthur Birembaut: "La contribution de Réamur à la thermométrie".

Jacques Proust: "Deux encyclopédistes hors de l'Encyclopédie—Philippe Macquer et l'abbé Jaubert".

Denis I. Duveen & Roger Hahn: "Deux lettres de Laplace a Lavoisier."

There are sections headed "Documentation et Informations" and "Analyses d'Ouvrages"; and finally, a general index to volume XI.